from cows in order to keep them in milk as long as possible. It is apparent from Bartlett's results that when cows do not conceive again within 3 to 6 months after calving, the milk solids will not show the marked increase which was observed in these animals from the sixth month till the end of lactation, but may even show a decline during that period. The birth rate among dairy cattle in South Africa is known to be comparatively low on account of the factors mentioned, and this may play a significant part in the production of poor quality milk in this country.

One noteworthy feature revealed by the relative curves (Fig. 7) and the data in Table 13 is that the inverse relationship between solids not fat and chloride is not maintained during lactation. It will be observed that during the first half of lactation there is a steady increase in chloride content and in the chloride-lactose index while the solids not fat and lactose on the other hand decline. From the 144th to the 228th day there is a steep rise in solids not fat while chloride remains at a more or less constant level. This is followed by a marked increase in solids not fat, chloride and chloride-lactose index, and a decrease in lactose.

When these changes are considered in conjunction with the increase in the number and the type of cells mainly found in milk towards the end of lactation they suggest that the udder, after being in a maximum functional state for some months, is no longer capable of maintaining the full rate of repair of the essential tissues in the gland, and it is probable that the synthetic cells show a gradual decline in activity while some may cease functioning altogether before the end of lactation. Lenfers (1907) indicated that with the advance of lactation parts of the udder around the periphery cease secretion. The result is that the secretory capacity of the alveoli and tubules is impaired. At the same time, on account of an intensification of the breaking down process of the alveolar epithelium, the membranes become more permeable thus permitting the passage of unchanged blood constituents into the milk. According to Espe (1938) serum globulin and albumin may increase at this time, and globulin remains high during the dry period, being probably associated with repair and regeneration of the alveoli. At the same time there is also an increase in the ash and notably in the calcium. It is this increase in the globulin, albumin and ash that is responsible for the high solids not fat content despite the decrease in lactose towards the end of lactation.

The composition of milk in the final stages of lactation is therefore very similar to that secreted in the first week after parturition. It is high in solids not fat, fat, chloride, globulin, albumin and ash, and low in sugar and casein. It may be, as Espe points out, that some of these constituents which are increased are concerned with regeneration of the udder and its preparation for the next lactation, but it appears too that there is in the pregnant cow a tendency for the secretory mechanism to gradually change over from the secretion of normal milk and to adapt itself for the synthesis of colostral milk for the next lactation.

(iv) *Individuality.*

It is a known fact that cows free from disease and maintained under identical conditions may show considerable individual variation in the composition of their milk, some persistently yielding milk falling below the prescribed standard for milk solids. In the absence of any known environmental conditions such as disease, season, malnutrition and stage of lactation to account for this phenomenon it must be accepted that the production of inferior quality milk by such animals is due to some inherent characteristic of the individual animal, the exact nature of which is not apparent.

In the general results the examination of the data obtained by the regular application of the six different criteria to quarter samples of milk from the cows over a period of approximately four and a half years, and covering 3 to 4 lactations, led to the conclusion that 12 out of the 40 quarters were persistently secreting milk which was abnormal in composition. It will be observed in the classification of the quarters into normal and abnormal in Table 5 that the 12 abnormal quarters were not distributed more or less uniformly among all the cows, but were confined to the twelve quarters of three animals (7905, 7909 and 7921). These three cows, representing 30 per cent. of the animals under observation were yielding inferior milk as the result of some individual characteristic of the cow herself or of the udder as a whole.

From the determination made on quarter samples of milk over the whole period the following calculations were made in respect of each cow and are detailed in Table 14 namely, the total yield in pounds of milk solids not fat and fat, the mean for each of the six criteria studied, and the number and percentage of samples that were abnormal to the various tests. In the above table the three abnormal cows are placed together at the head of the list.

The fat content of the milk of all ten cows was well above the legal requirement of 3 per cent. and therefore needs no further consideration in this section, though it must be pointed out that the average fat percentage of the three poor cows was far below that of any of the other seven. The highest mean of these three animals was 3·58 per cent., while the lowest of the other seven was 3·8 per cent.

Cow 7905 is obviously the animal with the poorest record as far as milk quality is concerned. The means for the various factors, excepting fat and cells, fell far short of the standards prescribed for normal milk, and the results of the tests applied also showed that the great majority of her milk samples were abnormal (Fig. 8). An interesting position is, however, revealed by the cell content of her milk, the average of which is lower than that obtained from any cow in the experiment. The significance of the low cellular content of all four quarters of cow 7905 is that it shows that this udder has been singularly free from bacterial activity during the whole period and that there is no likelihood of infection of the quarters with micro-organisms having a low pathogenicity being responsible for the secretion of abnormal milk in this case. It indicates too that the udder has been free from every type of secretory disturbance which might have caused a deterioration of the milk quality. Further, it may suggest a certain degree of sluggishness or inactivity on the part of the alveolar epithelium with a retarding effect on the synthetic mechanism with the result that insufficient lactose, casein and fat were synthesised for the volume of milk produced. The maintenance of osmotic equilibrium between the blood and milk consequently caused the increase in chloride.

The records for 7909 show a slight improvement on those of 7905. The mean solids not fat and lactose percentages are higher, and the chloride and chloride-lactose index show a corresponding reduction. The percentage of samples that were abnormal to the various tests is also lower. On the other hand the fat content of her milk was lower and the cell content significantly higher than that of 7905. Although this cow never showed any clinical evidence of mastitis or of other secretory disturbances, the detailed results of the various tests of the milk of her individual quarters, as given in the appendix, furnish evidence of abnormal activity within the gland. This was particularly noticeable during the second lactation. The pronounced increase in the cellular content of the milk which cannot be attributed to mere physiological changes suggests that some or other mildly pathogenic agent was active in the gland, which was probably partly responsible for the poor quality milk secreted.

Cow 7921 is also classed as a producer of inferior milk in virtue of the poor averages obtained by her for the whole period but it is very doubtful whether hereditary factors are solely responsible for the poor quality of her milk. The records in the appendix show that, with the exception of her left fore quarter which was 0·02 per cent. below the minimum for solids not fat, the milk from all quarters was normal in the first lactation. The deterioration was only revealed in the subsequent lactations. It will also be observed that the cell content of her milk was higher than that of any other cow. The relationship between cell content and bacterial activity will be discussed in the section on micro-organisms but it is relevant to point out at this stage that increased bacterial activity in the udder was probably the main cause of the decline of the quality of milk secreted by this cow.

In Figure 8 are presented four block graphs illustrating the percentage of milk samples from each cow that were abnormal to the tests for solids not fat, lactose, chloride and chloride-lactose index. Accompanying each block graph is a curve showing the mean for each cow for the relative factor. The graphs and curves demonstrate very clearly the marked differences revealed in all four of these constituents by the three cows secreting poor quality milk on one hand and the seven normal animals on the other hand. It will be observed that only in one instance, namely, the mean chloride percentage of 7921, did the mean for any one of these four factors of the three cows fall within the limits for normality.

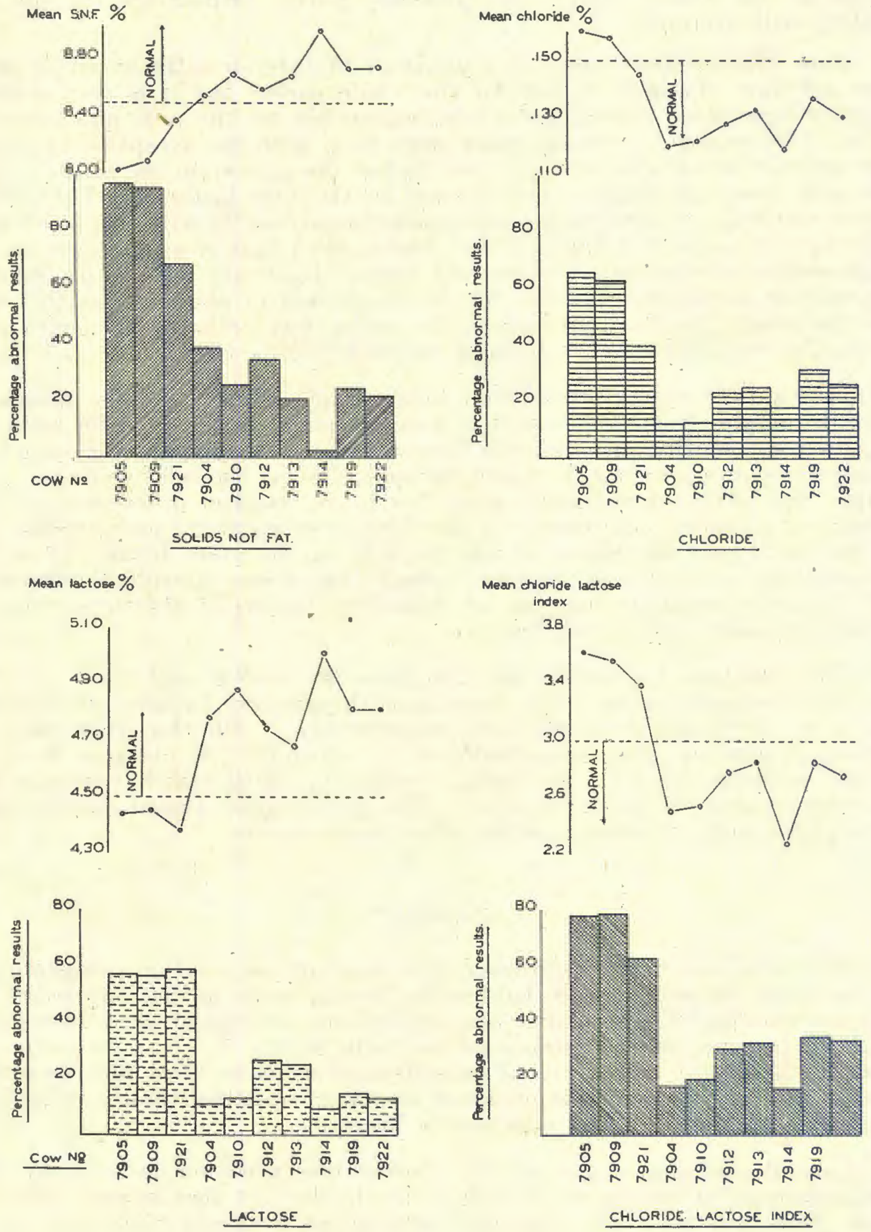
The analyses for solids not fat gave 96·5, 95·0 and 68·1 per cent. abnormal samples in the three cows, and the average fat-free solid content was 8·03, 8·09 and 8·36 per cent. respectively. On the other hand the highest proportion of samples deficient in solids not fat obtained from the normal animals was 38·3 per cent., yielded by 7904, which cow also gave the lowest mean (8·54) of the seven. The graphs show almost equally significant differences in respect of the other three factors.

Discussion.

It is obvious that the presence in a herd of such a high proportion as 30 per cent. of cows which habitually secrete milk falling far below the accepted standard for normality must constitute a factor of great importance in the depression in the quality of the bulk milk. It also emphasizes the need for the testing of individual animals in every dairy herd and the utilization of the information thus obtained for improving the quality of milk by exercising greater care and selection in breeding.

Careful consideration of all the observations made on each of the three cows concerned in this investigation points to the fact that in one (7921) the main cause was probably abnormal activity of unknown pathogens in the udder.

FIG. 8: PERCENTAGE OF ABNORMAL RESULTS GIVEN BY INDIVIDUAL COWS TO TEST FOR SOLIDS NOT FAT, CHLORIDE, LACTOSE AND CHLORIDE LACTOSE INDEX (BLOCK GRAPHS) AND MEAN S.N.F. CHLORIDE AND LACTOSE CONTENT AND CHLORIDE LACTOSE INDEX OF INDIVIDUAL COWS (CURVES)



In the second cow (7909) the same condition may have been a contributory factor. In the third (7905) no evidence was obtained of any disturbance in the udder. It is, therefore, concluded that in the latter cow, and to a large extent in 7909 the persistent secretion of abnormal milk was due to a hereditary or inherent weakness of the cow or of her udder. This aspect will receive fuller consideration in the section on conformation and structure.

There is a general tendency to associate high quality of milk with high production. A cow is judged and considered "good" merely because she gives a high yield. The records of the ten cows in this investigation provide convincing evidence that there is no such correlation between the quality and quantity of milk produced. Cow 7921 gave the highest yield, and if the records of 7905 had not been terminated in the middle of her fourth lactation she would have given the second best yield. Thus two of the three poor quality cows were the highest milk producers. On the contrary it would appear that high yield is associated with poor quality; and this fact has led Kay (1937) to suggest that it is possible that breeding for volume which has taken place without much regard for quality is one of the factors responsible for low quality milk.

That high milk production is, however, not always associated with poor quality is proved by the many records kept by various breed societies of high class pedigreed animals. According to these records most of the best milk producers also provide the highest quality milk. This must be attributed to the scientific methods and great selectivity practised by breeders of pedigreed animals, who attach as much importance to the quality as to the quantity of milk produced.

It appears that the indiscriminate breeding methods practised by many of the less scrupulous breeders of ordinary grade animals may lead to a disturbance of equilibrium between the different parts of the secretory apparatus whereby the synthetic portion responsible for the formation of the essential solids is not developed concurrently with the purely secretory portion. Sight is lost of the fact that the nutritive value of milk does not depend on the proportion of water it contains but mainly on the solids. This can be illustrated by examination of the records of cows 7922 and 7905 in Table 14. The former produced a total of 25,112 pounds of milk as against 27,057 by 7905. Notwithstanding the fact that her yield was 1,945 lb. less than that of 7905 cow 7922 gave 26·094 lb. more fat-free solids and 92·178 lb. more fat than 7905, and for breeding as well as for commercial purposes she thus should be classed as the better of the two cows.

(v) *Quarter Differences.*

The milk yield of the individual four quarters of the cow's udder has been studied by many workers, like Babcock (1889), Plumb (1896), Ingle (1902), Beach and Clark (1904), Swaboda (1905), Leather and Dobbs (1914), Scholz (1929), Filipovie (1932), and Turner (1934). In general the forequarters were found to be less productive than the rear. All the observations tend to indicate that the two forequarters yield approximately 40 per cent. and the two hindquarters approximately 60 per cent. of the total volume of milk produced.

The variations, if any, in the composition of milk from the individual quarters have not received the same intensive study as the yield, and most of the observations made in this regard are in respect of fat only. The data for those observations in which the other constituents of milk were considered were derived from only a small number of examinations, and consequently the results are inconclusive and unreliable.

Goldini (1914) concluded from his observations that the fluctuations of the quantity and quality of milk from the four quarters were unimportant.

Proks (1928) determined yield, specific gravity, fat, protein, ash, lactose, and solids not fat from the four quarters of six cows, and concluded that, while the milk from the four quarters was similar in composition, it was not identical, and the differences were often pronounced. Nottbohm (1928) obtained similar results from 18 cows. Mattick and Hallett (1929) noted distinct variations in yield, acidity, time of coagulation with rennet, and percentage butterfat of the milk from the individual quarters of a single cow during a lactation period of 11 months. Turner (1934) concluded that there is no tendency for the front quarters to secrete milk richer in fat than the rear or vice versa even though there is considerable difference in the average yield of milk.

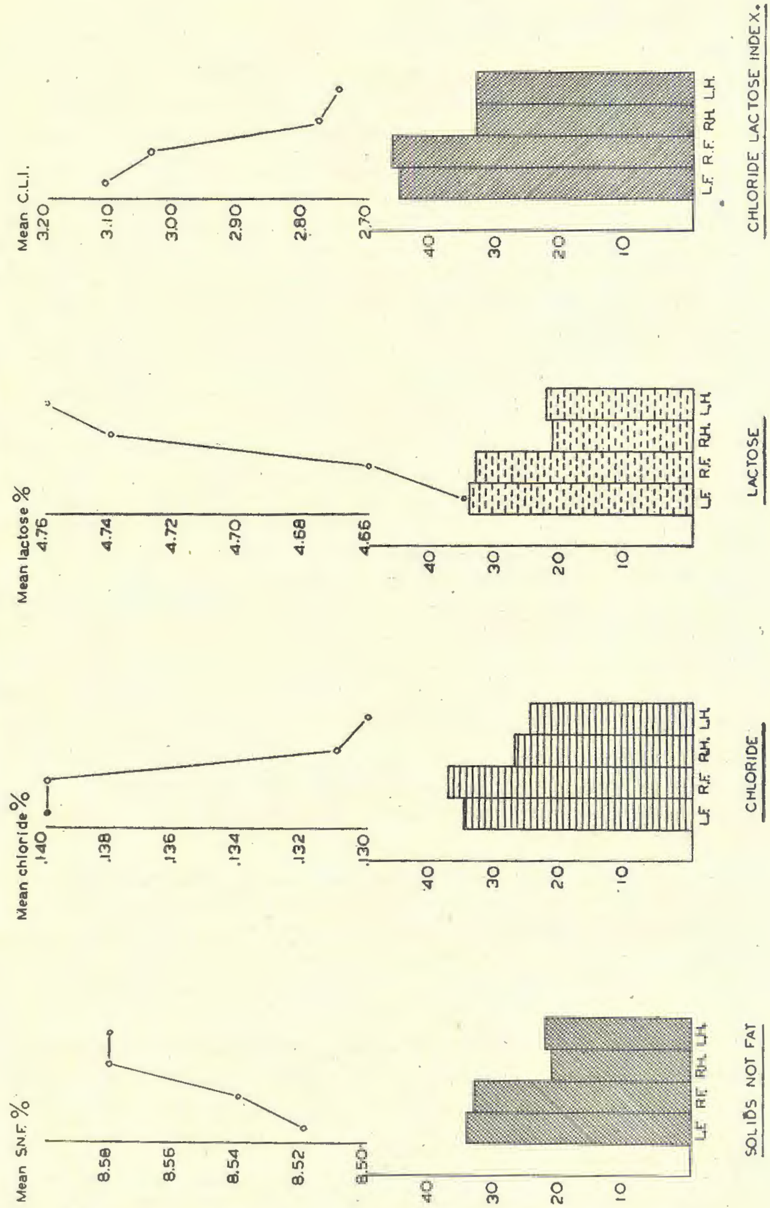
The results of all the observations made on the milk of the individual quarters of the ten cows in the course of this investigation are summarized in Table 15 and Figure 9.

TABLE 15.

Number of observations made in the different quarters; number and percentage abnormal, and means.

	RF	LF	RH	LH	Total	
No. of observations.....	369	369	369	369	1,476	Solids not Fat.
No. abnormal..........	156	174	138	142	610	
Percentage abnormal.....	42·3	47·2	37·4	38·5	41·3	
Mean percentage.......	8·54	8·52	8·58	8·58		
No. of observations.....	369	369	369	369	1,476	Fat.
No. abnormal..........	8	15	10	12	45	
Percentage abnormal.....	2·2	4·1	2·7	3·3	3·0	
Mean percentage.......	3·94	3·97	4·00	4·04		
No. of observations.....	347	347	348	346	1,388	Chloride.
No. abnormal..........	130	123	95	87	435	
Percentage abnormal....	37·8	35·3	25·1	25·1	31·3	
Mean percentage.......	0·140	0·140	0·131	0·130		
No. of observations.....	315	310	320	311	1,256	Lactose.
No. abnormal..........	106	108	69	70	353	
Percentage abnormal....	33·5	34·8	21·6	22·5	28·1	
Mean percentage.......	4·66	4·63	4·74	4·76		
No. of observations.....	314	311	319	311	1,255	Chloride-Lactose Index.
No. abnormal..........	145	140	107	104	496	
Percentage abnormal.....	46·2	45·2	33·4	33·4	39·5	
Mean percentage.......	3·04	3·11	2·78	2·75		
No. of observations.....	296	290	292	290	1,168	Cells.
No. abnormal..........	97	83	76	75	331	
Percentage abnormal.....	32·9	28·6	26·0	25·9	28·3	
Mean (thousands per ml.)	1,260	835	1,021	745		

FIG. 9: PERCENTAGE OF ABNORMAL RESULTS (BLOCK GRAPHS) YIELDED BY THE MILK OF THE INDIVIDUAL QUARTERS OF THE UDDER AND THE MEANS FOR EACH QUARTER. (CURVES)



Examination of the data in Table 15 shows that the milk produced by the two forequarters is very similar, in both composition and yield and the same applies to that secreted by the two hindquarters. Distinct differences in composition are, however, revealed by the milk obtained from the anterior and posterior halves of the udder. The results of all the criteria considered collectively disclose that the milk secreted by the two hindquarters is definitely of a higher quality than that of the two forequarters. Moreover the proportion of samples that were abnormal to the different tests was appreciably higher in the fore than in the rear quarters. The percentage of samples that were abnormal to tests for solids not fat, chloride, lactose and chloride-lactose index ranged from 33·5 to 47·2 in the forequarters and from 21·6 to 38·7 in the hindquarters. It will be observed that the mean chloride-lactose index for both forequarters was higher than the prescribed standard.

Although the differences between fore- and hindquarters are appreciable an analysis of variance showed that the mean differences revealed between quarters in the solids not fat, fat and lactose were statistically not significant. Examination of the data for chloride showed that with $P = \cdot 05$ the milk of both forequarters was significantly higher in chloride than that of the left hindquarter. No significant difference in the chloride-lactose index of the four quarters was revealed when $P = \cdot 01$, but with $P = \cdot 05$ the index for the left fore was significantly higher than that of both hindquarters.

While there are important differences between the front and rear portions of the udder, it would appear that the quality of the milk derived from the right and left halves of the gland is the same. When all the criteria are considered it would appear that the milk of the left forequarter is inferior to that of the right fore, but on the other hand that of the left hind is better than that of the right hind, thus compensating for the deficiencies shown by the left fore and maintaining an almost perfect state of equilibrium between right and left halves of the udder as regards milk quality.

The data for the individual quarters of each cow were also subjected to an analysis of variance but owing to the large number of calculations involved, this was confined to the two factors (solids not fat and chloride-lactose index) which are considered to offer the most reliable criteria for determining the quality of milk.

Cow 7922 is the only one which showed statistically significant differences in solids not fat percentage between quarters. With $P = \cdot 01$ the milk from the left hindquarter was significantly higher in solids not fat than that of both forequarters.

The analysis for chloride-lactose index revealed no significant inter-quarter differences in five cows (7904, 7905, 7909, 7910 and 7914). The extent of the variations shown by the other five cows is indicated in Table 16.

TABLE 16.

Variations in chloride-lactose index for individual quarters of five cows.

Difference between.	7912		7913		7919		7921		7922	
	P= ·05.	P= ·01.	P= ·05.	P= ·01.	P= ·05.	P= ·01.	P= ·05.	P= ·01.	P= ·05.	P= ·01.
R.F. R.H.	SS	SS	SS	NS	NS	NS	NS	NS	NS	NS
R.F. L.F.	SS	SS	NS	NS	NS	NS	SS	SS	SS	SS
R.F. L.H.	SS	SS	NS	NS	SS	NS	NS	NS	NS	NS
R.H. L.F.	NS	NS	NS	NS	SS	NS	SS	SS	SS	SS
R.H. L.H.	NS	NS	SS	SS	NS	NS	NS	NS	NS	NS
L.F. L.H.	NS	NS	SS	SS	SS	SS	SS	SS	SS	SS

In cow 7912 the chloride-lactose index for the right forequarter was significantly higher than that of all the other three quarters. The right forequarter of 7913 showed a significantly higher index than the right hind but only with $P = \cdot 05$. The index for the left hind, however, was significantly higher than that of the right hind and left fore also with $P = \cdot 01$. In 7919 significant differences between the right fore and left hind and the left fore and right hind were seen only with $P = \cdot 05$ but the marked difference between the left fore and left hind was revealed also with $P = \cdot 01$. The left forequarters of both 7921 and 7922 each had an index which was significantly higher than that of the remaining three quarters in each case.

The reasons for the inter-quarter differences that were detected in 7912 and 7913 will become apparent after consideration of the section on non-specific mastitis. The next section on conformation will account for the differences noted in the three other cows.

Discussion.

In a consideration of the causes of variation in the quality of milk secreted by the different quarters of the udder it is obvious that factors such as age, season and individuality, stage of lactation, nutrition, etc., will affect all quarters to the same extent, and cannot, therefore, be regarded as possible aetiological agents. It is also accepted that the different quarters of the mammary gland have the same supply of nutrients brought to them by the same circulating system with a blood stream that is of uniform composition, and that the synthesis and secretion of milk in the four quarters are controlled by the same nervous system and by the same supply of identical hormones, so that these factors can also be disregarded. Neither is it likely that the histological structure of the healthy mammary gland will differ so markedly in the individual quarters as to cause the variations that were observed in the quality of the milk secreted.

Disease or infection of one or more quarters is usually suspected when there are inter-quarter differences in the composition of milk, but with the exceptions which will be considered under non-specific mastitis, all pathological states were eliminated in this investigation. The logical deduction, therefore, is that there must be one or more features which are characteristic of the forequarters and are responsible for the poorer quality of milk produced by them as compared with that secreted by the hindquarters. It may be surmised that the blood which supplies the forequarters is not so rich in the precursors of milk as that which goes to the hindquarters. It must be noted, however, that the anterior quarters derive their blood from the same mammary artery which supplies the hindquarters and that the anterior branch of this artery is given off before any of the precursors should have been removed by the hindquarters. Again it may be postulated that the capillary anaestomoses in the forequarters may not be as complete as in the hindquarters resulting in an inadequate blood supply, but in that case the natural result would be a decrease in quantity rather than in quality fo milk produced.

The one remaining factor which suggests itself is the gross anatomy of the udder, and this aspect will receive consideration in the next section.

(vi) *Conformation and Structure of the Udder.*

The histological structure and the physiology of the normal udder, its blood supply and nervous and hormonal control have been the subject of intensive study by many different investigators, but the available literature contains no indication or evidence that the healthy udder has shown any variation in one or more of these controlling factors, which would produce inter-quarter differences in the composition of the secretion from the four portions of the gland. In the absence of any proof to the contrary, it must, therefore, be assumed that the milk from the different quarters of the normal healthy udder is similar in composition.

In the previous section, however, convincing evidence was adduced to show that inter-quarter differences, which are significant in some cases, have been detected in the composition of milk, and that these variations appear to be most pronounced between the anterior and posterior halves of the udder. On the whole the milk derived from the two forequarters is inferior in quality to that secreted by the hindquarters.

During the course of these investigations it became apparent that the tendency for one or two quarters persistently to secrete milk which was below the standard of that obtained from the other quarters of the same gland was most noticeable in animals with badly shaped asymmetrical udders. This observation warranted further investigation into the part played by the conformation and structure of the mammary gland in the production of abnormal milk. Such a study may not only elucidate the variations in the quality of milk from different quarters but may also throw light on some of the factors concerned in the production of abnormal milk by the udder as a whole.

While the conformation and structure of the udder have received widespread attention from the aspect of the productive potentialities of this gland, no reference to any attempt hitherto made to correlate these two factors with the quality of milk secreted can be found. This is understandable when one considers the many difficulties with which such an investigation would be fraught. Chief of these is the great variety of intrinsic characteristics of the udder itself, which either individually or collectively may influence the composition of the milk, such as size, shape, weight, storage capacity, skin covering, elasticity, histological structure, permeability of the membranes, etc.

Another great handicap which besets the research worker in this field is the fact that the mammary gland, especially in the living animal, does not lend itself to measurement by certain definite units of size, weight and volume or capacity. For these reasons it is appreciated that an evaluation of the various qualities of the gland must of necessity be based mainly on the judgment of the examiner, and whatever standards or methods are employed, the personal element cannot be entirely avoided.

No histological examination has hitherto been made of any of the udders and the conclusions formed about their structure are based only on visual and manual examination. The procedure followed was first to list all the factors pertaining to the udder itself, which it was thought might influence the composition of the milk, and then to ascertain to what extent the udder of each cow conformed with these. The following characteristics were considered in this manner:—

Symmetry was judged by viewing the udder from all sides and noting the development of the individual quarters with special reference to their relation to the udder as a whole.

Evenness or Smoothness indicates the fullness of the udder and the development of the glandular tissue as is characterized by the absence of deep sulci or indentations between the quarters and the absence of roughness or corrugations on the surface of the gland.

Skin covering denotes the character and the degree of attachment of the skin which covers the gland. The ideal skin should be thin, elastic and loosely attached to the gland allowing it to distend fully on filling with milk.

Yieldability is the degree of responsiveness of the udder to pressure applied to it from without, and is an indication of the elasticity of the gland.

Mellowness or softness denotes the consistency of the udder as determined by deep palpation and kneading. Softness and pliability indicate an abundance of glandular tissue, while a firm, hard consistence is evidence of excessive fibrous tissue and is characteristic of " meaty " or " fleshy " udders.

Free space is the space just above the teats which can readily be compressed between the fingers and indicates to some extent the storage capacity of the udder.

Teats in themselves cannot influence the quality of milk, and not so much the size and shape of the teats were considered in this case as their attachment to the udder, their spacing and whether they were hanging level or not.

Collapsibility is the degree to which the udder collapses or shrinks after it has been milked out. The good elastic udder should shrink away to nothing and hang in folds, and its texture should feel soft and spongy after it has been completely emptied.

The best method for judging the udders on these points was considered to be by means of a score card on which the points were awarded under each heading. The maximum number of points a cow could obtain was 20, and the number of points gained by each cow under the various headings is shown in Table 17.

The estimation of the quality of the udder in this manner was not based on a single examination, but rather reflects the opinion formed of each udder by the examiner after inspection and palpation of the udder, both before and after milking at monthly periods throughout the investigation.

TABLE 17.

Score card for udders.

	7904.	7905.	7909.	7910.	7912.	7913.	7914.	7919.	7921.	7922.
Symmetry	9	10	9	14	10	10	12	3	8	5
Evenness	10	11	3	14	10	14	13	8	7	7
Teats	10	12	8	12	8	13	12	6	7	6
Skin	9	4	8	11	10	12	14	13	11	14
Yieldability	6	5	8	8	7	9	11	10	7	10
Softness	6	4	7	9	8	9	12	10	5	11
Free Space	12	7	9	11	11	13	14	11	4	13
Collapsibility	10	5	9	12	9	12	14	10	8	12

The above score card is further elucidated by a brief description of the individual udders and by the photographs in Fig. 10.

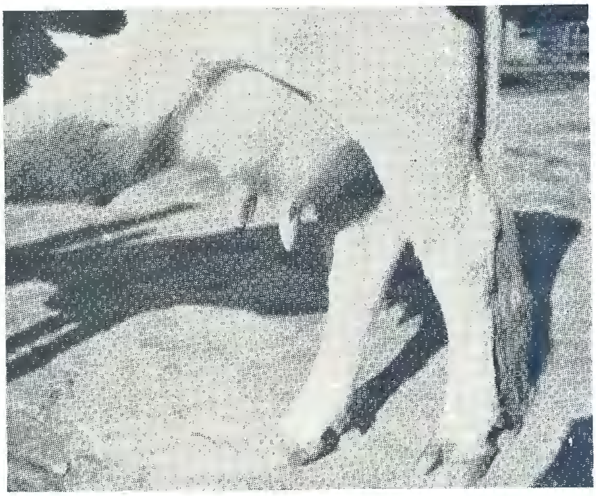


Fig. 10.—Cow 7904.

Fig. 10.—Cow 7909.

Fig. 10.—Cow 7910.

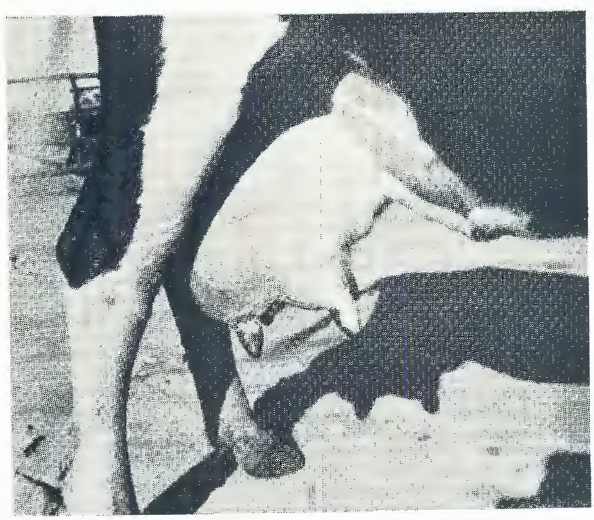


Fig. 10.—Cow 7912.

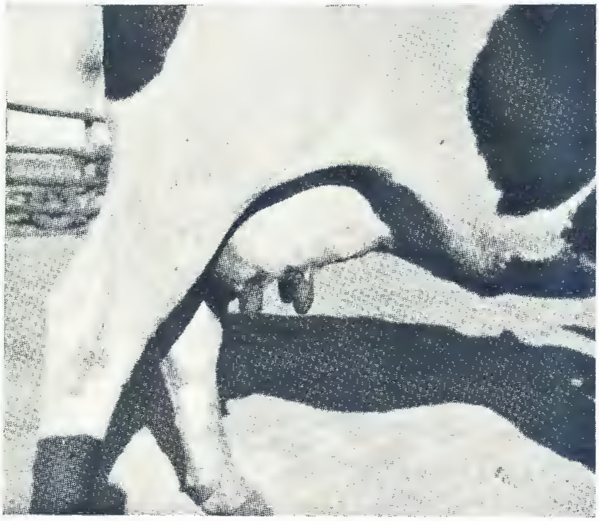


Fig. 10.—Cow 7913.

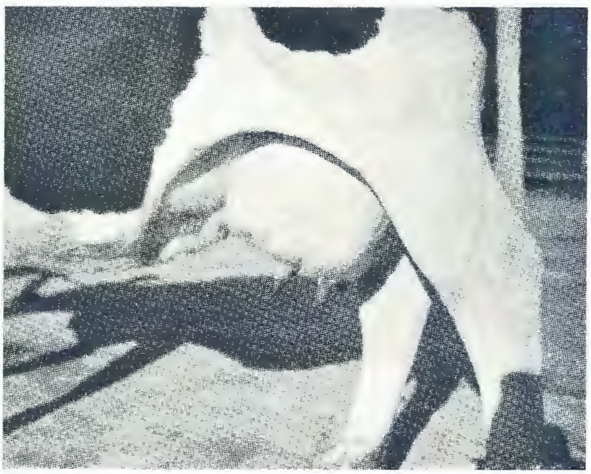


Fig. 10.—Cow 7914.

Fig. 10.—Cow 7919.

Fig. 10.—Cow 7921.

Fig. 10.—Cow 7922.

7904.—A moderate udder in all respects. The teats are squarely attached and level, but the division between fore- and hindquarters is rather too prominent. The greatest defect from the point of view of quality is that palpation revealed excess fibrous tissue resulting in poor quality yieldability and mellowness.

7905.—A large, symmetrical, well-shaped, smooth udder with big teats squarely attached. On superficial examination one would conclude that this udder was capable of giving a high yield of good quality milk. The outward appearance, however, is deceptive. As is evident from the points scored she obtained good marks for those points judged by visual examination (symmetry, evenness and teats) but the weaknesses were revealed by palpation. This showed a somewhat thick skin, firmly stretched over the gland, a lack of yieldability, mellowness and collapsibility, and failure to shrink after milking. This is a good example of a " fleshy " or " meaty " udder. Unfortunately this cow died before her udder was photographed. She is therefore not included in Fig. 10.

7909.—This gives the impression of being " all teats and no gland ". The teats are squarely attached, but are bunched together, and the indentations between the teats both from side to side and in the antero-posterior direction are deep and too conspicuous. There appears to have been an overdevelopment of the teats at the expense of glandular tissue. The anterior attachment of the gland is abrupt instead of being extended under the abdominal wall.

7910.—A well-proportioned, symmetrical udder with the forequarters showing good development and extending well forward under the abdomen. Teats are well spaced, squarely attached and hang level. Surface of the udder is smooth and even. While there is no evidence of excessive fibrous tissue, the texture of the gland is not as soft and pliable as that of some of the other cows.

7912.—A large, pendulous udder, the result of excessive stretching of the suspensory ligaments caused by post parturient oedema after the second calving. This also produced a certain degree of distortion of the udder and teats, though it did not appear to affect the yield and composition of milk with the exceptions to be noted in the section on non-specific mastitis. The skin is loose, the tissue soft and pliable, and the udder contracts well after milking.

7913.—A well-developed, though not perfectly symmetrical, udder with a smooth surface and teats spaced well apart. This gland is very similar in all respects to that of 7910.

7914.—When considered only from the point of view of production this udder is on the small side, but otherwise shows all the characteristics of a good udder, such as fine shape and symmetry with properly developed forequarters having their anterior attachment well forward under the abdomen; teats not too big, well spread and squarely attached; surface of gland smooth with subcutaneous veins prominent; skin thin, soft and loose; glandular tissue soft and mellow with no indication of excess fibrous tissue, and shrinking well after milking. It will be observed in Table 17 that this is the only cow which obtained a more or less uniform number of points under all the headings.

7919.—A very badly shaped udder with extremely poor development of the forequarters which instead of being placed anterior to the hindquarters are almost lateral to them, and the four teats are situated almost in a line extending from side to side. The skin shows an excess of hair, but is soft and loosely attached. The glandular tissue also is soft and has good yieldability, though the two forequarters and particularly the left fore show marked underdevelopment of the glandular tissue.

7921.—An udder with good capacity but poorly shaped and badly attached, not showing sufficient extension in front and in the rear. It lacks symmetry, the right half being better developed than the left. The demarcation between quarters is too prominent. The teats are well shaped but not level, the left fore particularly being drawn up due to poor development of that quarter.

7922.—This udder resembles that of 7919 in the marked underdevelopment of the forequarters which, however, in this case occupy their proper position, namely, anterior to the hindquarters. The teats, though squarely attached, hang unevenly, the two front teats, particularly the left, being drawn up and thus hanging much higher than the rear ones. The udder gives the impression of marked atrophy of the forequarters such as may be caused by advanced chronic mastitis, yet it has never shown secretory disturbance of any kind, and on palpation the glandular tissue of all quarters is soft and pliable.

The correlation between the variations in the composition of the milk from the anterior and posterior halves of the udder and defective conformation and structure of the gland is best shown by studying the differences between the two halves as given in Table 18 in conjunction with the description of the udders and the points scored in Table 17.

In addition to the means for solids not fat, chloride, lactose and chloride-lactose index for the anterior and posterior halves of the udder, Table 18 also includes the total volume of milk produced by the fore- and hindquarters, and in each case the percentage of the whole produced by the two respective halves. Further, it shows the symmetry index for each udder, which furnishes a reliable indication of the conformation of the udder and of the relative yield of the anterior and posterior portions. The symmetry index was determined from Turner's (1934) formula:—

$$\text{Symmetry index of udder} = \left\{\begin{matrix}\text{Percentage of total milk yield}\\ \text{of rear half}\end{matrix}\right\} - \left\{\begin{matrix}\text{Percentage of total}\\ \text{milk yield of front}\\ \text{half}\end{matrix}\right\} - 20$$

This index is based on the hypothesis that the forequarters secrete 40 per cent. and the hindquarters 60 per cent. of the total volume of milk. The normal udder would thus have a symmetry index of 0. An udder with excessive development of the rear half would have a positive index, while a negative index would indicate excessive development of the front half.

TABLE 18.

Difference in yield and composition of milk secreted by the anterior and posterior halves of the udder.

Cow.	Milk Yield.						Solids not Fat.		
	Total Yield.	Forequarters.		Hindquarters.		Symmetry Index.	Fore-quarters Average Percentage.	Hind-quarters Average Percentage.	Difference.
		Yield.	Percentage of Total.	Yield.	Percentage of Total.				
7904........	17891·9	7163·2	40·1	10728·7	59·9	—0·2	8·535	8·550	0·015
7905........	27057·9	10470·7	38·7	16587·2	61·3	3·6	8·000	8·055	0·055
7909........	19812·4	6568·4	33·2	13244·0	66·8	13·6	8·065	8·100	0·035
7910........	27717·0	12256·9	44·2	15460·1	55·8	—9·4	8·675	8·690	0·015
7912........	26425·7	11563·4	43·7	14862·3	56·3	—7·4	8·575	8·610	0·035
7913........	19647·3	9096·4	46·3	10550·9	53·7	—12·6	8·660	8·670	0·010
7914........	23219·1	8594·5	36·6	14624·6	63·4	6·8	9·000	9·000	0
7919........	19473·3	4159·2	21·4	15314·1	78·6	37·2	8·700	8·745	0·045
7921........	30156·4	12195·8	40·4	17960·6	59·6	—0·8	8·365	8·360	0·005
7922........	25112·9	8787·9	35·3	16234·0	64·7	9·4	8·675	8·800	0·125

Cow.	Chloride.			Lactose.			Chloride-Lactose Index.		
	Fore-quarters Average Percentage.	Hind-quarters Average Percentage.	Difference.	Fore-quarters Average Percentage.	Hind-quarters Average Percentage.	Difference.	Fore-quarters Average Percentage.	Hind-quarters Average Percentage.	Difference.
7904........	0·125	0·115	0·010	4·75	4·80	0·05	2·62	2·38	0·24
7905........	0·164	0·157	0·007	4·41	4·47	0·06	3·75	3·53	0·22
7909........	0·161	0·156	0·005	4·40	4·51	0·11	3·69	3·45	0·24
7910........	0·126	0·118	0·008	4·83	4·94	0·11	2·64	2·42	0·22
7912........	0·136	0·120	0·016	4·63	4·85	0·22	3·06	2·50	0·56
7913........	0·132	0·135	0·003	4·71	4·65	0·06	2·76	2·95	0·19
7914........	0·125	0·115	0·010	4·97	5·01	0·04	2·37	2·17	0·20
7919........	0·147	0·128	0·019	4·73	4·89	0·16	3·07	2·62	0·45
7921........	0·149	0·141	0·008	4·30	4·46	0·16	3·54	3·24	0·30
7922........	0·136	0·124	0·012	4·72	4·90	0·18	2·95	2·53	0·42

In the previous section it was shown that the milk produced by each of the two forequarters of 7922 was significantly lower in solids not fat percentage than that of her left hindquarter and this was the only one of the ten animals in which a significant difference between quarters in solids not fat percentage was detected. The chloride-lactose index, however, revealed significant inter-quarter differences in five cows (Table 16). The cause of the secretion of abnormal milk by two of these, namely the right fore of 7912 and the left hind of 7913 will be discussed in the section on non-specific mastitis. None of the remaining three cows (7919, 7921 and 7922) at any time showed evidence of non-specific mastitis, and an inflammatory state of one or more quarters can be disregarded in any attempt to find the cause of the variations shown between quarters in these animals. It will be shown later that a high degree of bacterial activity was revealed in all quarters of 7921, and this may have been a contributory factor to the low quality of milk produced by her. Since, however, this affected all four quarters equally, it cannot be regarded as the primary cause of the milk of the left forequarter being markedly inferior to that secreted by the other three quarters.

A characteristic feature which is common to all the three last-mentioned cows and which is illustrated both in the relative photographs and by the low marks awarded to them for symmetry, evenness and teats (Table 17), is the very poor development of the forequarters and notably the left fore in each case. This bad conformation was not acquired as the result of mastitis or any other environmental factor but was congenital. The fact that only these poorly developed quarters of the three cows which showed a marked lack of symmetry of the udder secreted milk which showed a significant degree of inferiority to that produced by the other quarters of the same cows warrants the conclusion that the structure of the quarters concerned was responsible for the variations noted in the composition of the milk yielded by them.

Discussion.

The theory that bad conformation and structure of the udder may cause a depression in the quality of the milk secreted immediately provokes the question as to the manner in which such physical defects of one portion of the udder may have a detrimental effect on the milk produced.

On Turner's hypothesis that the normal, well-developed, symmetrical udder is so constructed that the anterior half will produce 40 per cent. and the posterior half 60 per cent. of the total volume of milk, it can be presumed that the relative ratio between the volume of glandular tissue in the fore and hind portions of the udder is 2:3. Further, it would be a justifiable assumption that the circulatory supply to the four quarters is so regulated that it enables the anterior and posterior halves of the udder to produce their respective portion of the total milk yield, and that the milk from all quarters will be of uniform composition. Examples of such udders are supplied by cows 7914 and 7910 in both of which the udder is well balanced, the symmetry index is near 0, and there are no significant differences in the composition of the milk from the quarters of the same cow.

In underdevelopment of the forequarters such as is seen in 7919 and 7922 there is a deficiency in glandular tissue and the ratio between the volume of synthetic tissue in the fore- and hindquarters will be bigger than the presumptive normal of 2:3. The logical sequel would be a corresponding reduction in the milk yield by the forequarters, but the crucial question is whether this reduction in yield is proportionate to the decrease in glandular tissue whereby the inadequate volume of tissue in the quarter or quarters concerned is enabled to synthesize sufficient milk solids to maintain the composition of the milk at the same level as that produced by the other quarters. In 7919, for instance, the forequarters only produced 21·4 per cent. instead of 40 per cent. of the total milk yield, giving the very high positive symmetry index of 37·2. Yet even this poor yield appears to be in excess of what the poorly developed forepart of the udder was capable of producing. Notwithstanding the very marked degree of underdevelopment shown by the two forequarters of 7922 they yet produced nearly their full quota, namely, 35·3 per cent. of the total yield with the comparatively low positive symmetry index of 9·4. This was apparently far in excess of the potentialities of the anterior half of the gland and it will be observed that the difference in the quality of milk produced by the fore and hind portions of the udder is more marked in this cow than in 7919.

There is apparently no mechanism whereby the circulatory supply to an underdeveloped quarter can be correspondingly reduced in order to prevent "choking" of the gland with a volume of blood greater than it is capable of handling. It is therefore probable that in all udders a volume of blood with milk precursors sufficient to constitute approximately 20 per cent. of the total output of milk is conveyed to each of the two forequarters. When, however, owing to poor development, the glandular portion is not able to synthesize sufficient solids for the volume of milk produced, an excessive diffusion of the soluble salts and other constituents which are derived directly from the blood takes place resulting in the secretion of milk containing an excess of chloride and a deficiency of lactose.

Another factor which may be concerned in the production of inferior milk by some quarters of badly shaped udders is the possibility of the deformity of the quarters concerned causing a reduction in their storage capacity and elasticity. This would have the result of increasing the intramammary pressure at an unduly fast rate between milkings, the effect of which would be to retard or even suppress the synthesis of fat, lactose and casein in the alveoli and tubules.

The theories advanced to account for the inter-quarter variations in the composition of milk may also be offered to explain the inherent weakness or inability of some udders to produce milk of normal composition.

Bad conformation of the udder cannot be held responsible for the secretion of inferior milk by a cow like 7905 which obtained more points for symmetry, evenness of udder, and teats than several cows which yielded better milk. Her weakness appeared to be in the histological structure of the whole gland. The firm, meaty type of udder covered with a thick inelastic skin suggests an excess of fibrous tissue and an inability to expand properly when filling in order to accommodate the volume of milk secreted. As pointed out by Hammond (1936) the whole structure of the cow's udder is designed for the relief of pressure on the secretory alveolar cells. The elastic coat, the elastic fibres round the ducts and the thin elastic skin, producing an udder which "shrinks away to nothing" after the milk is withdrawn, or which will expand easily when milk is secreted into it, is a mechanism for keeping intra-mammary pressure in the udder as low as possible compatible with the accommodation of a large volume of milk. The inability of the udder to expand easily on account of a paucity of elastic tissue, excess of fibrous tissue, and a firm thick skin will raise the intramammary pressure more rapidly than in the soft, mellow, elastic udder with the result already described.

In brief, therefore, it is postulated that the persistent secretion of abnormal milk by individual quarters or by the udder as a whole may be due to inability on the part of the organ to keep the intra-mammary pressure as low as possible on account of a lack of elasticity or inadequate storage capacity. It may also be due to increased permeability of the alveolar membranes or to defective synthetic mechanism, both of which will result in a proportionately larger amount of water and soluble salts from the blood passing into the milk than the milk solids formed in the alveoli.

It is not claimed that the theories advanced have been established beyond doubt, but strong evidence in their support has been adduced. More intensive study, especially histological examination of such udders, is required to substantiate the views put forward.

Two points of considerable practical importance have emerged in this study. In the first place it has been established that good conformation and structure of the udder is essential to ensure uniformity and quality of milk produced by all four of the quarters. Secondly it has been suggested that the habitual secretion of abnormal milk by individual cows which are free from disease is due to structural defects of the udder tissue, which are probably hereditary characteristics. Accordingly the need for stressing these factors in breeding dairy animals is obvious.

(vii) *Non-specific Mastitis.*

The term non-specific mastitis is employed with great latitude by many workers, and is generally applied to all cases in which bio-chemical examination of milk reveals abnormalities, while bacteriological examination fails to detect any micro-organisms which might be held responsible for the abnormalities noted.

Hastings and Beach (1937 and 1939) in a study over two lactations of the composition of milk from 31 cows, free from pathogenic organisms, found that the milk of certain animals deviated from the usual standard for chloride content and for pH and catalase values to such a marked extent and persisted so long as to indicate an abnormal condition in one or more quarters of the gland. They concluded that the deviations were such as would be expected when some part of the gland was inflamed. All their efforts to determine the aetiological factor and to transmit the condition failed, and they finally inclined to the view that the cause was inherent in the animal.

In a three-lactation study of a herd of 18 heifers free from udder streptococci Peterson (1938) found similar conditions to be present and observed that the incidence of the abnormality increased from lactation to lactation. He concluded that the fact seems well established that inflammation of the mammary gland does exist in the absence of streptococci or any other recognised pathogen in the milk.

Peterson, Hastings and Hadley (1938) were not able by exhaustive culturing of milk, or by inoculation of laboratory animals, or by histological examination to discover any organism other than diphtheroids and cocci (micrococci or staphylococci) regularly present in udders secreting abnormal milk. They found little or no reason for believing that diphtheroids could be responsible, and concluded that non-specific mastitis is not caused by staphylococci or micrococci because (*a*) no correlation can be found between the presence of these organisms in milk and the incidence of non-specific mastitis; (*b*) no specific organisms have been associated with any number of cases; (*c*) the organisms usually appear to be similar to or identical with the microflora of normal udders; (*d*) non-specific mastitis has never been transmitted experimentally. They concluded that while positive proof is lacking, the most probable aetiological cause of the abnormality appears to be a virus.

Hastings and Peterson (1940) used the term " non-specific mastitis " to indicate that no specific cause was found for the disturbances that were observed in the milk.

The application of the term "non-specific mastitis" to all cases in which the milk is abnormal in composition but contains no pathogenic organisms is based on the hypothesis that any alteration in the composition of milk necessarily implies an inflammatory state of the udder. " Mastitis " means an inflammation of the mammary gland, and its use should be confined to those cases in which clinical examination of the gland reveals the cardinal symptoms of inflammation, namely, heat, pain and swelling in the acute form, and fibrosis or induration in the chronic type.

Sufficient evidence has been forthcoming in this work to prove that the secretion of abnormal milk without any clinical or bacteriological manifestation of inflammation or infection is not an uncommon occurrence, and that some cows like 7905 which has never shown the least suspicion of any form of mastitis persistently secrete milk which does not conform with the accepted bio-chemical standards for normal milk. It has also been suggested that the secretion of abnormal milk in such cases is due to an inherent or congenital characteristic of the animal concerned, and that it is not associated with an acquired or environmental condition.

In this investigation the term " non-specific mastitis " is used in its true sense and is applied only to those cases in which definite evidence of inflammation was present, and in which no pathogenic bacteria were detected in the milk. This form of the disease was observed in two of the ten cows, namely, 7912 and 7913.

In the sixth month of her first lactation 7912 developed an acute catarrhal mastitis of the left forequarter. This was characterised by pain and swelling of the gland, a purulent condition of the milk and a reduction in milk yield. The clinical symptoms lasted for only four days but chloride, which reached a maximum of 0·324 per cent., remained abnormally high for three weeks, while solids not fat declined from 8·59 per cent. in the 5th month to 8·38 and 8·28 per cent. in the 6th and 7th months respectively, before it again assumed an upward trend. Stage of lactation might have been a contributory factor in the depression of fat-free solids at this period, but it will be observed in the records that none of the other three quarters showed such a marked drop at that time. In the fifth month of lactation, that is some time before there was any other perceptible indication of udder disturbance, the cell count rose to 4,083,000 per ml. During the height of the attack the cells were too numerous to count, but they decreased rapidly and were within normal limits 8 weeks after the attack.

Within a week after her second calving this cow developed a marked post-parturient oedema of the whole udder. During the early stages this was accompanied by an increase in chloride though this was not above that which could normally be expected within the first two weeks of calving. The oedema persisted for a month, but it will be noted in the records that this apparently had no effect on the composition of the milk and that the milk of all four quarters was normal in every respect 32 days after the second calving. This oedema was responsible for the permanent stretching of the suspensory ligaments which gave rise to the subsequent marked pendulousness of the gland.

Cow 7912 next ran into trouble when her right forequarter contracted acute catarrhal mastitis in the 6th month of her second lactation. The onset of this was sudden, though the cell content showed a striking increase to over 3 and 5 millions in the 4th and 5th months respectively. This, with the similar observations recorded in the left forequarter above, suggests that an increase in cellular content is generally the first indication of an impending secretory disturbance. The clinical symptoms subsided after four days but the chloride and chloride-lactose index remained high for the rest of the lactation period. Solids not fat dropped from 8·57 per cent. to 8·28 per cent. during the acute stages and then gradually increased. At this period, however, the other three quarters showed a similar decline in solids not fat. Stage of lactation may, therefore, have been the principal cause of the depression, though it is possible that the disturbance in the right fore may also have affected the synthesis and secretion of milk in the other three quarters.

In the 7th month of her first lactation cow 7913 developed acute catarrhal mastitis in both forequarters. This was characterized by the usual clinical symptoms, by increase in chloride to 0·172 and 0·234 per cent. in the right and left forequarters respectively and by a drop in sugar content to 3·43 per cent. in the right fore while that of the left fore could not be determined. The cells increased to 1,680,000 and 8,225,000 per ml. Solids not fat dropped from 8·70 per cent. to 8·52 per cent. during the attack and to 8·38 per cent. the month after in the case of the right fore, and from 8·66 per cent. to 8·23 and 8·40 per cent. in the left fore. The two hindquarters showed no depression in solids not fat during the same period. In both forequarters the milk was normal in all respects within 8 weeks after the attack.

Ten days after her second calving 7913 showed evidence of a subacute catarrhal mastitis in the left hindquarter with slight swelling and firmness of the gland, a purulent condition of the milk, increase in chloride content to 0·238 per cent. and a cell count of 10,000,000 per ml. The solids not fat percentage of this quarter for the first four weeks was only 8·33 as against 8·77 for the following month. Three weeks later chloride had dropped to 0·162 per cent. and cells to 287,000, and at 60 days after calving the milk was normal in all respects.

On cursory examination it would appear that the udder has remarkable regenerative powers, and that the damage done by an acute attack of non-specific mastitis is soon repaired and the affected gland restored to full normal production within a few weeks after the attack. Close study of the data, however, reveals that in some cases the recovery is more apparent than real, and that the initial restoration to complete functioning of the quarter may be followed by deterioration which is more pronounced than can be normally expected. This is illustrated by comparing the mean composition of the milk of the individual quarters of 7912 and 7913 as presented in Table 19 and by means of block graphs in Figure 11.

In their first lactation the two forequarters of 7912 both yielded a higher percentage of solids not fat than the hindquarters, and the chloride and chloride-lactose index of the right fore was lower than that of the other three quarters. The acute mastitis of the left forequarter in the 6th month of the first lactation showed its immediate effect on the chloride and chloride-lactose index of the milk of that quarter by raising the average of these two factors

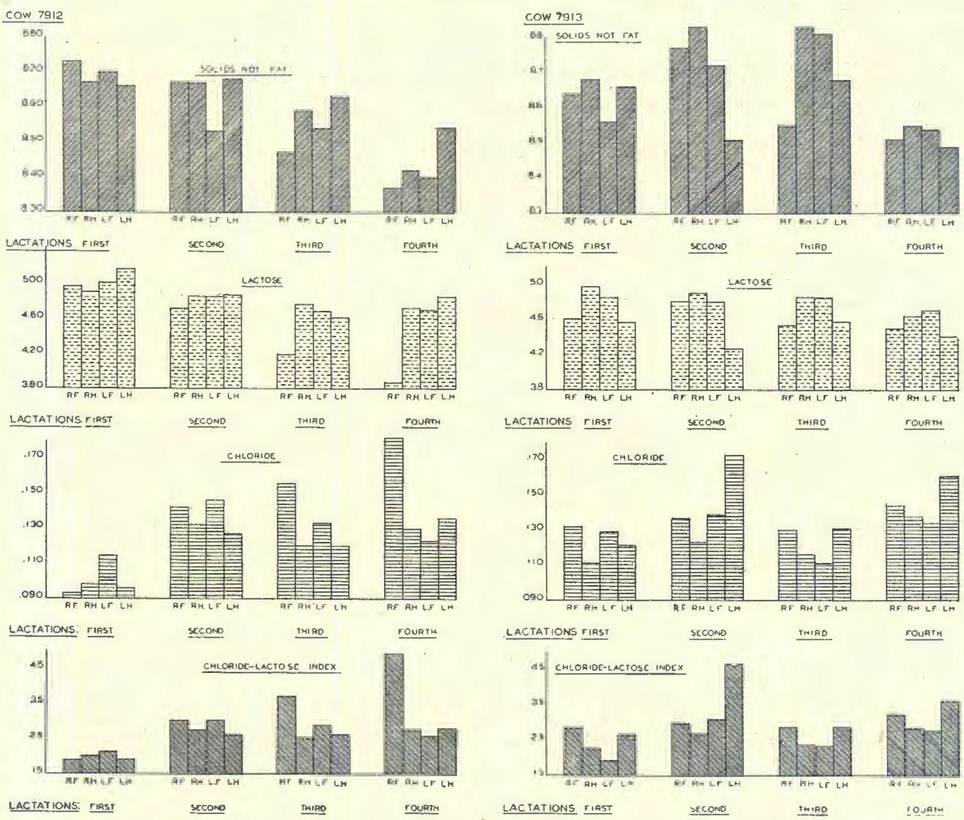
TABLE 19.

Composition of milk of the individual quarters of cows 7912 and 7913 over four lactation periods.

	Quarter.	Cow 7912.				Cow 7913.			
		1st Lactation.	2nd Lactation.	3rd Lactation.	4th Lactation.	1st Lactation.	2nd Lactation.	3rd Lactation.	4th Lactation.
Solids not Fat, Percentage	RF	8·73	8·67	8·47	8·37	8·64	8·77	8·55	8·51
	RH	8·67	8·67	8·59	8·42	8·68	8·83	8·83	8·55
	LF	8·70	8·53	8·54	8·40	8·56	8·72	8·81	8·54
	LH	8·66	8·68	8·63	8·50	8·66	8·51	8·68	8·49
Fat, Percentage	RF	4·23	4·97	4·15	3·71	4·12	4·09	3·93	3·70
	RH	3·98	4·51	4·34	3·53	4·13	4·26	4·13	3·68
	LF	4·28	4·57	4·30	3·60	4·13	4·14	4·09	3·67
	LH	4·33	4·72	4·23	3·68	4·19	3·89	3·84	3·52
Chloride, Percentage	RF	·093	·142	·156	·182	·132	·137	·130	·144
	RH	·098	·132	·120	·130	·111	·123	·116	·138
	LF	·114	·146	·133	·123	·129	·139	·111	·134
	LH	·096	·127	·120	·136	·121	·173	·131	·161
Lactose, Percentage	RF	4·97	4·71	4·19	3·88	4·61	4·81	4·54	4·51
	RH	4·90	4·85	4·77	4·72	4·97	4·89	4·85	4·65
	LF	5·01	4·85	4·68	4·70	4·86	4·80	4·84	4·71
	LH	5·17	4·87	4·62	4·86	4·57	4·27	4·58	4·42
Chloride-Lactose Index	RF	1·89	3·03	3·71	4·91	2·86	2·96	2·88	3·23
	RH	2·00	3·74	2·53	2·77	2·29	2·67	2·39	2·89
	LF	2·13	3·03	2·88	2·58	1·94	3·09	2·32	2·79
	LH	1·91	2·61	2·63	2·80	2·69	4·18	2·86	3·63
Cells (thousand per ml.)	RF	53	4837	9231	3504	942	255	851	942
	RH	1079	978	897	1004	899	151	1608	2282
	LF	1589	1011	1242	1512	1975	352	667	629
	LH	894	854	2552	479	251	1207	3153	1894

above those of the other three quarters. The full effect on the solids not fat percentage was only revealed in the second lactation when it was markedly lower than that of the other three quarters. During the 6th month of the second lactation the right forequarter suffered with the result that the chloride and chloride-lactose index for both forequarters were appreciably higher than those of the hindquarters. The ultimate depressing effect of the disease on the solids not fat content of the milk of the two forequarters was revealed in the third and fourth lactations when the deterioration was particularly marked in the right fore. This depression of the solids not fat and lactose was accompanied by a corresponding rise in chloride and chloride-lactose index.

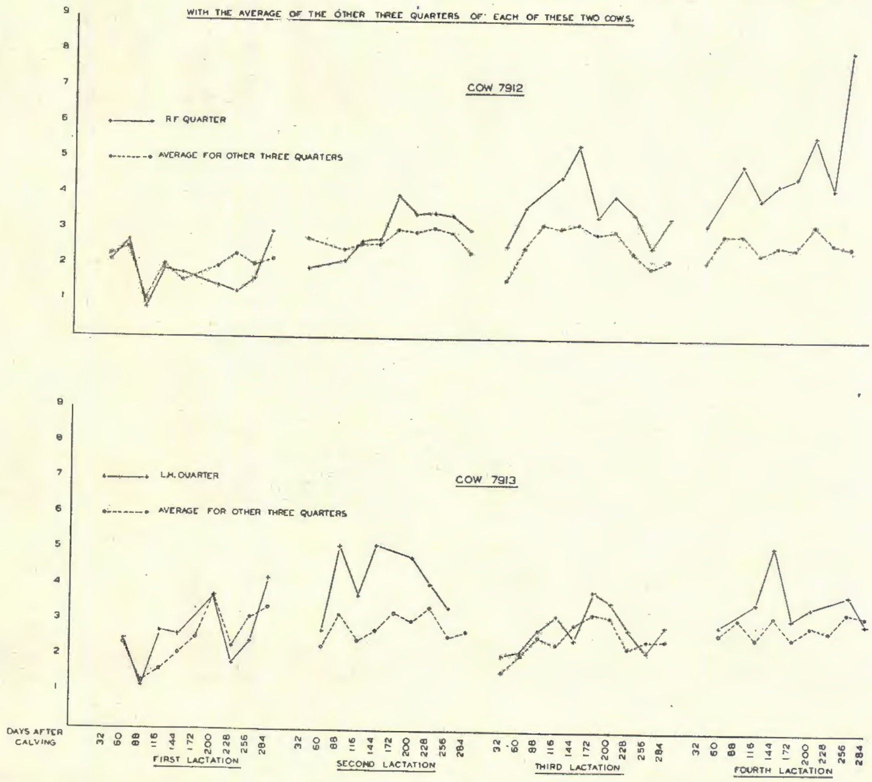
FIG 11 THE MEANS FOR EACH QUARTER FOR EVERY LACTATION OF COWS 7912 AND 7913



The attack suffered by the two forequarters of 7913 in the seventh month of the first lactation though very acute at the time, apparently did not leave the same lasting results as in 7912. Comparison in this case is, however, complicated by the fact that the left hind also became involved early in the second lactation with the result that there was a marked drop in its solids not fat and lactose and an increase in chloride and chloride-lactose index. The data in Table 19 and the block graphs indicate that while recovery was apparently complete in the left fore of 7913, the full and efficient functioning of the gland was never restored in the right fore and left hindquarters. Their milk was appreciably lower in solids not fat and lactose and higher in chloride and chloride-lactose index in the third and fourth lactations than that of the other two quarters.

The analysis of vari ance in Table 16 shows that the chloride-lactose index of the right fore of 7912 was significantly higher than that of the other three quarters, and that the index for the left hind of 7913 was also significantly higher than that of the right hind and left forequarters of this cow. The secretory portions of these two quarters were therefore affected to a greater extent than that of any of the other quarters by the non-specific mastitis. The classification in Table 5 also reveals that these two are the only quarters of the cows that were persistently secreting normal milk, that had to be relegated to the doubtful class on account of the deterioration in the quality of their milk.

FIG 12: CHLORIDE LACTOSE INDEX OF THE RIGHT FOREQUARTER OF COW 7912 AND OF THE LEFT HINDQUARTER OF COW 7913 COMPARED WITH THE AVERAGE OF THE OTHER THREE QUARTERS OF EACH OF THESE TWO COWS.



The effect of the mastitis on the milk secreted by these two quarters is further illustrated by the curves in Fig. 12. In the curve for 7912 the continuous line represents the chloride-lactose index of the right forequarter while the average index for the other three quarters is indicated by the broken line. During the whole of the first lactation and up to the fifth month of the second period the line for the right fore is either contiguous to or below that for the average. During the attack of mastitis, however, it crossed the line for the averages and continued above it for the rest of the second and whole of the third and fourth lactations. Moreover the gap between the two curves gradually widened and was quite marked in the fourth lactation, thus suggesting that deterioration was more rapid in the right fore than in the other three quarters.

During the first lactation of 7913 the chloride-lactose index curve for the left hind followed more or less the same trend as that of the average for the other three quarters, but after the mastitis in the first month of the second lactation it showed a rapid rise and continued high throughout the remainder of this period. A reapproachment signifying an improvement in the quality of the milk secreted by this quarter was shown in the third lactation, but this was apparently only temporary and the gap became wider in the fourth lactation.

Discussion.

Non-specific mastitis characterized by clinical symptoms of inflammation, changes in the composition of the milk and by the absence of known pathogens was diagnosed in five quarters of two cows during the period of 4½ years. In only one of the five quarters was recovery apparently complete. Although the clinical evidence of inflammation subsided and could not subsequently be detected by palpation, the depression in the quality of the milk secreted by the other four quarters was such as to indicate that the changes produced in the quarter were of a chronic nature. In two of these quarters the deterioration was so marked that the quality of the milk secreted by them was significantly lower than that of the other quarters of the same animal.

All attempts to discover the aetiological agent failed in every case. The fact that the disease appeared successively in five quarters and that two cows standing next to each other in the stable were affected suggests that the causal factor might have been contagious. On the other hand this may have been a mere coincidence, and it must be pointed out that none of the other cows contracted the disease.

An important aspect which may have some importance as a predisposing factor is that all five cases occurred in the second half of the first and the first half of the second lactations. It has already been pointed out that there was an exceptionally large number of secretory disturbances during the second lactation which resulted in chloride reaching its maximum during this period. A reasonable assumption in this connection would be that within the first year or two after the initiation of lactation the mammary gland undergoes its maximum development, and that, therefore, it will be more susceptible to deleterious influences than at any other subsequent stage.

An interesting phenomenon shown by at least two of the five quarters was the pronounced increase in the cellular content of their milk a month or two before the appearance of clinical symptoms of mastitis. This is indicative of abnormal activity in the quarters and suggests that the toxic agent was of low potency resulting in it having to wage a prolonged battle before finally breaking down the natural powers of resistance of the quarter.

Infection with an unknown virus cannot be completely disregarded in the search for the causal agent in non-specific mastitis. If the presumption of low pathogenicity of the causal organism be accepted, one must also consider the possibility of one or more of the so-called normal bacteria of the udder developing a pathogenicity and under favourable conditions being capable of provoking an inflammation of the gland. This theory receives further consideration in the following section.

(viii) *Micro-organisms.*

Literature on the bacterial content of milk contains many references to the " normal bacterial flora " of the udder. This is based on the hypothesis that a variable number of certain types of bacteria are always present in milk aseptically drawn from the udder, and that the mammary gland is the normal habitat of such organisms. Actually this is an erroneous assumption because, strictly speaking, the normal udder and the milk secreted by it should be free from all bacteria. In practice this is rarely the case, though individual quarters, especially in the first lactation, frequently secrete bacteria-free milk. By common usage the term " normal udder flora " is now generally applied to all bacteria found in the udder, which have not been proved to be pathogenic.

These presumably harmless bacteria are being regarded with increasing suspicion in virtue of the fact that quarters which secrete abnormal milk frequently contain an abnormally large number of them, while the pathogenic organisms are conspicuous by their absence. Some workers have even attempted to prescribe a limit for the number of micro-organisms and to regard as abnormal anything in excess of that number. Thus Messner (1937) gave a limit of 300 bacteria per ml. for healthy milk, and considered that if repeated tests show more than this number, a state of " microbism " exists even if no mastitis is evident.

Hastings and Beach (1937) pointed out that nothing is known of the products produced by these bacteria, especially as they grow in the udder, and hence nothing of their pathological effect. They suggested that certain forms of bacteria may be present in quarters supplying abnormal milk, that are not present in other quarters. Peterson and co-workers (1938) concluded that the so-called non-specific mastitis or rather secretory disturbance of unknown aetiology was not produced by the staphylococci or micrococci usually found in the udder. Subsequently, however, Hastings and Peterson (1940) inclined to the view that bacteria of certain types may produce slightly injurious compounds which, acting over considerable periods, may cause a detectable effect in the milk. This is in accordance with the view expressed in the previous section, namely that the cause of non-specific mastitis is one or more micro-organisms of low toxicity which must be active over a long period before they can overcome the resistance of the udder.

The difficulties experienced in obtaining necessary equipment and the many staff changes necessitated by war conditions made the determination of bacterial counts with the same regularity as the other tests impossible, and it is unfortunate that no counts were made in the second or third lactations of a few animals. With these exceptions, however, the survey was sufficiently comprehensive to give a reliable indication as to the number of micro-organisms present in each quarter.

The average bacterial and cellular contents of the individual quarters for each lactation are detailed in Table 20. The bacterial counts for all 40 quarters were uniformly low during the first lactation. Subsequently, however, an abnormal increase in both bacteria and cells was observed mainly in those quarters in which there was a history of acute mastitis or other secretory disturbance, such as the right fore of 7912 and the left hind of 7913.

Although cow 7921 never showed clinical manifestations of mastitis it will be observed that the marked increase in the cellular content of the milk from all four of her quarters from the beginning of the second lactation, accompanied by a corresponding rise in chloride and chloride-lactose index and decline in solids not fat and lactose, is more pronounced than can under ordinary circumstances be attributed to deterioration due merely to advancing age. Unfortunately no bacterial counts were made during her second lactation, but the flora of the milk from all four quarters was abnormally high during her third and fourth lactations. All the evidence points to the fact that for some or other reason the normal protective mechanism of all four quarters of this udder broke down soon after the second calving with the result that bacterial activity in the quarters developed almost unchecked with obvious detrimental results on the composition of the milk.

High bacterial content of the milk is frequently, but not invariably, accompanied by a high cell content. The detailed records in the appendix provide many instances in which the bacteria were high and cells low, and vice versa.

Similarly no definite correlation could be established between the other factors studied and the udder flora. It appears that only in those cases in which there was definite evidence of secretory disturbance was high bacterial content of the milk attended by an increase in cells, chloride and chloride-lactose index and a decrease in solids not fat and lactose. No abnormal increase in the number of bacteria or cells was noted in those cases in which the poor quality of the milk was due to an hereditary weakness, as in 7905 or to poor conformation of the udder as in the forequarters of 7919.

The data in Table 20 and the complete records in the appendix show that micro-organisms when once they are established in the udder, appear to remain permanently, and tend to increase progressively with advancing age. This is in agreement with the findings of Munch-Peterson, Murnane and Bull (1940) who came to the conclusion that micrococcal infections, once established in a quarter, are very persistent and appear to be more or less permanent.

Discussion.

The rôle played by the so-called normal bacteria of the udder in the causation of non-specific mastitis is still obscure, but the marked increase noted in both bacteria and cells in cases showing definite evidence of secretory disturbance suggests three possibilities:—

(1) The unrestricted multiplication of the "normal" bacteria in a quarter may result in the abnormally large number of micro-organisms or their products in such a state of microbism providing the necessary irritation in the quarter to provoke an inflammation. Against this, however, must be recorded the observation previously reported, namely, that there did not appear to have been a striking increase in the bacterial content just prior to the onset or even during the course of the acute attack of mastitis, whereas the disease was heralded by a noteworthy increase in cells in some cases. This suggests that the causal organism was present and active for some time before clinical symptoms were shown. The bacteria did frequently show an increase but only some time after the acute stage of the disease had passed. In

some cases, for instance, in the right fore of 7912 and the left hind of 7913, this increase is most striking only months or even years after the primary disease.

TABLE 20.

Average bacterial and cell content of individual quarters for every lactation.

Cow.	Quarter.	Lactation 1.		Lactation 2.		Lactation 3.		Lactation 4.	
		Bact. per ml.	Cells thousands per ml.	Bact.	Cells.	Bact.	Cells.	Bact.	Cells.
7904........	RF	36	96	74	249				
	RH	49	74	44	105				
	LF	129	133	119	82				
	LH	51	230	120	57				
7905........	RF	125	78	43	202	380	379	20	497
	RH	15	36	28	282	400	410	10	295
	LF	156	89	299	169	155	443	55	891
	LH	371	75	73	147	38	212	10	316
7909........	RF	276	714	2,614	4,010	860	2,472		
	RH	373	221	790	524	304	1,331		
	LF	19	122	2,229	1,565	1,400	824		
	LH	664	963	830	1,155	360	990		
7910........	RF	10	305	4,350	223	1,586	579	4,100	554
	RH	12	1,559	3,000	343	1,071	941	1,800	767
	LF	46	363	338	77	37	212	1,787	878
	LH	46	199	733	66	630	558	3,160	885
7912........	RF	13	53	1,006	4,837	1,150	9,231	11,480	3,504
	RH	66	1,079	488	998	95	897	234	1,004
	LF	48	1,589	967	1,011	725	1242	986	1,512
	LH	85	894	525	854	80	2,532	302	479
7913........	RF	21	942	1,682	255	1,125	851	2,550	942
	RH	33	899	233	151	900	1,608	3,625	2,282
	LF	84	1,975	2,944	352	332	667	1,340	629
	LH	50	251	1,937	1,207	1,900	3,153	13,875	1,894
7914........	RF	22	469	800	511	620	1,232	1,525	1,366
	RH	30	311	100	517	630	1,310	1,250	1,270
	LF	25	174	2,250	415	840	645	1,333	1,911
	LH	67	225	1,000	255	535	581	1,250	1,989
7919........	RF	63	542	—	170	130	177	800	427
	RH	30	96	—	963	94	212	373	284
	LF	45	317	—	195	33	187	423	878
	LH	53	79	—	55	376	93	240	507
7921........	RF	120	432	—	1,259	2,028	1,691	9,000	2,592
	RH	261	1,760	—	2,310	4,325	4,311	7,333	4,780
	LF	19	578	—	1,447	6,356	2,824	16,500	2,798
	LH	94	359	—	1,217	2,350	1,604	8,600	2,889
7922........	RF	60	1,385	100	607	1,916	978	2,900	1,299
	RH	23	1,794	100	893	328	339	1,233	473
	LF	65	356	50	1,168	2,711	1,087	1,417	1,464
	LH	42	692	—	134	102	169	510	589