PB 151375

NBS

Technical Note 16

SOME APPLICATIONS OF STATISTICAL SAMPLING METHODS TO OUTGOING LETTER MAIL CHARACTERISTICS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS
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JULY 1959

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Norman C. Severo
Arthur E. Newman
Shirley M. Young
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The work described in this Report was sponsored by the Office of Research and Engineering, Post Office Department.

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PREFACE

The National Bureau of Standards is developing equipments and systems for improving letter sorting by automation. Therefore it is necessary to determine the nature and characteristics of mail in post offices.

Since the volume of mail is much too large for complete piece counts to be feasible, statistical sampling methods of known and adequate accuracy must be used. The present paper is the first step in the effort to develop such methods as applied to letter size mail characteristics.

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Coordinator, Post Office Project

ACKNOWLEDGMENT

The authors wish to express appreciation to Inspector John Falconer, Post Office Department, and Mr. Martin Stark, Section 12.5, NBS, for their assistance in supervising the collection of data involved in the sampling procedures; to Mr. Stanton Russell, Section 12.5, NBS, for mechanized recording of top and bottom clearance space and perfecting the device for measuring the size characteristics of letters; to Inspectors Frank Wright, Washington, D.C., R.T. Rock, Los Angeles, and Ronald Nielson, San Francisco, for their assistance in recording the data; to Dr. Churchill Eisenhart, Chief of the Statistical Engineering Laboratory (Section 11.3), NBS, for many helpful suggestions concerning the analyses of these studies and for a critical reading of the report; to other members of the Statistical Engineering Laboratory for consultation and assistance in preparing this report, especially to Mrs. Lola S. Deming for a detailed statistical review of the original manuscript; and to the members of the NBS Fact Finding Group for the Post Office Project for their contribution in the tabulation of the data. Finally, gratitude is expressed to the Postmasters and staffs of the Washington, D. C., Los Angeles, and San Francisco Post Offices for their cordial cooperation.

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Some Applications of Statistical Sampling Methods To Outgoing Letter Mail Characteristics

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This paper presents applications of statistical sampling procedures especially devised to procure information about the characteristics of outgoing letter mail. The results of four separate studies carried out in the Washington, D. C., San Francisco, and Los Angeles post offices are herein summarized. The techniques used in the various studies were developed so that the required information would be of predetermined reliability and could be gathered without the use of a large staff and without interrupting the flow of mail. The four studies presented concern: 1) letter size and color characteristics, 2) ratio of hand canceled mail to machine canceled mail, 3) top and bottom clearance space of an addressed envelope, 4) proportions of long and short letters.

1. Conclusions

This section presents what appear to be the major conclusions of this report. These conclusions are elaborated upon in detail in the following sections.*

1.1 Letter size and Color characteristics. The study of the characteristics of letter size mail from the cities of San Francisco, Los Angeles, and Washington, D.C. led to the conclusions that follow.

Table 1 is a summary showing all categories of mail sampled, the sample size, size characteristic averages, and tolerance limits. The table gives, for each type of mail studied, the average height, length, and thickness of the letters collected in the study. In addition, statistical tolerance limits are given for both the length and height characteristics. These limits are 99% limits implied by the data at hand with confidence coefficient .95. Thus, for example, for Cancel Long Regular mail from San Francisco, where a total of 291 letters were sampled, the tolerance limits of 3 9/16 and 4 5/16 inches are recommended for height. This means that we expect 99% of all Cancel Long Regular mail to have heights between 3 9/16 and 4 5/16 inches - and we shall be correct in this expectation unless the sample from which we deduced this result was anomalous to an extent that would arise no more than 1 time in 20.

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* Care should be exercised in attempting to draw precise conclusions to other post offices.

TABLE 1. A summary for Cancel, Metered, Cull, and Bulk mail of (i) sample size, (ii) average height, length, and thickness, (iii) predicted lower and upper 99% tolerance limits with confidence coefficient .95.

		Height			Length			Thickness
	Sample Size	Average Height	L.T.L.	U.T.L.	Average Length	L.T.L.	U.T.L.	Average Thickness
				(in inches)				
CANCEL LONG MAIL								
Regular S.F.	291	4.13	3 9/16	4 5/16	9.30	a	10 5/16	.09
Air Mail S.F.	51	4.14	3 5/16	4 5/16	9.41	a	10 9/16	.12
Regular L.A.	581	4.13	3 9/16	4 13/16	9.34	a	9 9/16	.07
Air Mail L.A.	289	4.16	3 9/16	5 5/16	9.34	a	9 9/16	.08
Regular D.C.	1253	4.19	3 9/16	5 1/16	9.20	a	10 7/16	.09
Air Mail D.C.	222	4.22	3 1/16	5 1/16	9.22	a	10 1/16	.09
CANCEL SHORT MAIL								
Regular S.F.	463	3.62	3 1/16	4 13/16	6.18	4 5/16	a	.07
Air Mail S.F.	66	3.74	3 9/16	4 5/16	6.29	5 5/16	a	.09
Regular L.A.	800	3.74	2 5/16	6 5/16	6.27	3 13/16	a	.07
Air Mail L.A.	330	3.90	3 1/16	5 9/16	6.30	4 1/16	a	.08
Regular D.C.	1545	3.70	3 1/16	5 1/16	5.99	4 4/16	a	.08
Air Mail D.C.	248	3.80	3 1/16	5 1/16	6.10	5 1/16	a	.08
METERED MAIL								
S.F.	616	3.85	3 1/16	5 9/16	7.81	5 1/16	11 5/16	.11
CULL MAIL*								
Regular S.F.	1133	4.07	2 13/16	5 5/16	7.91	3 13/16	11 1/16	.10
Air Mail S.F.	197	4.13	3 5/16	5 1/16	7.87	4 13/16	9 9/16	.10
Regular L.A.	1924	4.26	2 12/16	5 1/16	8.03	4 3/16	10 9/16	.08
Air Mail L.A.	322	4.26	3 5/16	5 5/16	7.85	5 1/16	10 13/16	.09
BULK MAIL								
Bundles S.F.	290	4.56	3 1/16	b	8.45	4 5/16	b	.09
Letters S.F.	985704	4.43	3 3/16	b	8.46	5 5/16	b	.07
Bundles L.A.	414	4.86	2 13/16	b	8.57	4 1/16	b	.09
Letters L.A.	1620823	4.91	2 13/16	b	8.59	4 1/16	b	.08

a/ By definition, short letters are less than 7 9/16 inches in length and long letters are equal to or greater than 7 9/16 inches.

b/ No upper limits could be calculated because of the limitations of the measuring device. Table 33 gives estimates of the percentage of mail whose measurements are greater than these limitations.

* The tolerance limits for the Cull mail have been calculated from sample distributions truncated as described on page 73. Estimates of the percentage of mail cut off by this truncation process are given in Table 32.

1.1.1 Cancel. There appear to be no differences among the three cities with respect to the letter size characteristics (height, length, and thickness) studied for Cancel mail. Furthermore, the control charts for height and length show a remarkable amount of agreement from sample to sample within a specific type of mail for a given city. The fact that the sample averages fall within their respective control limits is strong evidence that the differences observed from sample to sample are due to chance rather than some assignable cause which would tend to alter or change the letter size characteristics (see Figures 2 through 6).

It is recommended that wherever information is desired regarding the characteristics of Cancel mail that the sampling plan used in this report for that type mail be adopted. This sampling plan has been designed to obtain information about certain types of mail while at the same time utilizing efficiently current postal methods of canceling letter mail.

1.1.2 Cull. In general there are no differences between San Francisco and Los Angeles with respect to the letter size characteristics studied for Cull mail.

The study of Cull mail was started in Los Angeles after sampling had been initiated to obtain letter size characteristics data on Cancel mail. It was believed that the Cull study would provide information about a much larger class of mail than studied at the facing table (i.e., Cancel mail). The results, while informative and unbiased in that the methods provide good estimates of the averages, are subject to more variability than is evidenced in the Cancel mail study. If additional information of this type is desired, then it is recommended that further investigation be made of the sampling procedures with the aim of devising, if possible, a method subject to less variability. It may well be that the method used here is adequate for the purposes intended.

1.1.3 Bulk. There are apparently significant differences between San Francisco and Los Angeles with respect to the characteristics studied for Bulk mail. However, more theoretical consideration needs to be given to the problem of analyzing the Bulk data.

1.1.4 Color. In general there appears to be no difference between the cities studied, San Francisco and Los Angeles, with regard to the color of envelopes. On the average, 80% of the envelopes are white.

1.1.5 Recommendations. If it is desirable to make each of the cities already studied for letter size characteristics more complete and comparable, then additional studies should be made for:

a. Air mail in San Francisco

b. Metered mail in each of the three cities

c. Color in Washington, D. C.

d. Cull mail in Washington, D. C.

The measuring device used in all three cities was not large enough to enable measurements to be made of oversized mail. Thus any letter that was larger than either scale on the template (approximately 7 1/2" x 12") was lumped in a catch-all class. Therefore, much information concerning this type mail was lost. Additional study should be made of the oversize category if more detailed information concerning its distribution is desired. This, of course, would involve using a larger measuring device.

1.2 Ratio of hand canceled to machine canceled mail for D.C. The results of the sampling do not strictly apply to letter size mail, but instead include mail that may be considered as "slightly larger." The results of the statistical analyses were that the ratio, expressed as a percentage, of hand canceled mail to machine canceled mail was 2.11% $\pm$ 0.21 for A.M., 3.94% $\pm$ 0.88 for P.M., and 3.34% $\pm$ 0.61 for All Day.

We strongly recommend that a sampling procedure such as used here be employed whenever similar type ratios are desired. This sampling method would provide ratios that are otherwise obtained by complete enumeration.

1.3 Top and bottom Clearance Space of an addressed envelope. Essentially two studies were conducted to determine top and bottom Clearance Space, i.e., the distances from the top edge of the first line of intelligence of the address to the top edge of the envelope and from the bottom edge of the last line of intelligence of the address to the bottom edge of the envelope. The San Francisco - Los Angeles study represents a refinement of the one initiated in Washington, D. C.

1.3.1 Washington, D. C. memorandum

1. A distance of 3/4 of an inch be used for the top Clearance Space of an addressed envelope.

2. No tolerance limit is recommended for the bottom Clearance Space.

1.3.2 San Francisco and Los Angeles memorandum

1. A distance of 0.9 of an inch be used for the top Clearance Space of an addressed envelope.

2. No tolerance limit is recommended for the bottom Clearance Space of an addressed envelope for stamped mail. A tolerance limit of 0.4 of an inch is recommended for the bottom Clearance Space of an addressed envelope for Metered mail.

1.4 Proportions of Long and Short letters. This study was concerned with determining the ratio of Long letters to

Long plus Short letters for machine cancel mail. The ratio is not the same in the morning as it is in the evening. Approximately 30% of A.M. letters (from 10 A.M. to 4 P.M.) are Long and approximately 50% of the P.M. letters (from 4 P.M. to 11 P.M.) are Long. The overall daily percentages are 46% for San Francisco and 45% for Los Angeles and the confidence limits for each ratio are approximately 41% and 50%.

2. General Introduction.

This report is the second in a series which presents applications of statistical sampling procedures especially devised to procure information about the characteristics of outgoing letter mail. The results of four separate studies carried out in the Washington, D. C., San Francisco, and Los Angeles post offices are herein summarized. The techniques used in the various studies were developed so that the required information could be gathered without the use of a large staff and without interrupting the flow of mail. It is hoped that these statistical sampling plans will be used again whenever the same type of information is desired. Four studies are described in this report. Unless otherwise indicated these studies were conducted during the peak A.M. and peak P.M. periods of mail flow

2.1 Specific studies.

2.1.1 Letter size and color characteristics. This study was initiated to determine the length, height, thickness, and color characteristics of outgoing letter mail. The details are presented in Section 3 The samples taken at both the San Francisco and Los Angeles post offices were studied for all four of these characteristics. The samples taken in Washington, D. C. were studied only for length, height, and thickness.

2.1.2 Ratio of hand canceled mail to machine canceled mail. This study was conducted at the Washington, D.C. post office to determine the proportion of hand canceled mail to machine canceled mail. The study is presented in Section 4 .

2.1.3 Top and bottom Clearance Space of an addressed envelope. This study was conducted to determine the top and bottom Clearance Space of an addressed envelope. Two separate studies were made, one conducted in Washington, D.C., and the other in San Francisco and Los Angeles. The details are given in Section 5.

2.1.4 Proportions of Long and Short letters. This study is confined to samples taken at the San Francisco and Los Angeles post offices. Ratio figures for Long and Short letters are given for both morning and evening periods. The details are given in Section 6.

Each of these studies utilizes statistical sampling techniques for acquiring the appropriate information. No elaborate counts of mail are made in any case. Using statistical methods relatively few letters need to be studied as compared to a complete enumeration. By applying the theory of probability and statistics, the desired information can be provided with a predetermined reliability. Furthermore we are able to predict how well our results will agree with results obtained by a future study -- providing, of course, that no substantial changes occur in the characteristics studied.

2.2 General remarks on statistical sampling

2.2.1 The purpose of a sampling study.

The purpose of any sampling study is to give information about the population of interest, without having to make a complete enumeration of the population involved. The sample is not taken for the information it provides in itself. It is of the utmost importance that the population to be studied (the target population) be carefully defined. The definition of the target population dictates the types of mail to be sampled.

In one of the applications, we are interested in characterizing envelope dimensions by collecting data on a few hundred randomly selected letters. A complete enumeration would have required examination of several million envelopes. We have been particularly careful to define the target populations from which samples are taken and about which conclusions may be drawn.

2.2.2 The nature of a statistical sampling study. A statistical sampling procedure is designed to obtain a reliable estimate of what would have been found from a complete (and completely accurate) enumeration of the population. It describes a procedure for collecting data to estimate with known reliability the characteristics of the population, without having to examine the entire population.

A distinctive feature of statistical sampling plans (aside from the savings in cost) is that the property of representativeness is inherent in the sampling plan itself, not in the particular sample at hand. This enables one to state how well the results of a particular sample are likely to agree with results of other samples for which the same sampling plan is used.

In a statistical sampling procedure, the samples are selected at random. It is this random selection that gives assurance that the results of the sample can be related to the population with a known degree of reliability. More details about methods of selecting a random sample are given below.

A random sample is selected in accordance with fixed rules and must not be confused with a haphazard selection of samples. If we were interested only in the characteristics of the sample itself, we might simply walk around the post office and select any batch of mail that meets our fancy. The information thus obtained would be limited strictly to the sample itself and could not be applied to any other batch of mail in the post office. Using a random procedure for selecting the samples from some well defined population enables us to make general statements about whole classes of mail.

Each of the studies of this report utilizes sampling procedures designed specifically to determine the information required. The sampling must, in all cases, be done in accordance with the well designed rules of randomization. Thus, whenever at all possible -- and this was almost always -- we have employed some mechanical device such as dice, a lottery system, or a table of random numbers to insure the randomness of the selected items of the samples. The importance of objective randomization cannot be overstressed, and is well illustrated in a rather lengthy quotation from an article by Cochran, Mosteller and Tukey [2] 1/.

1/ Figures in brackets refer to the list of references given on page 124 .

"Whether by biologists, sociologists, engineers, or chemists, sampling is all too often taken far too lightly. In the early years of the present century it was not uncommon to measure the claws and carapaces of 1000 crabs, or to count the number of veins in each of 1000 leaves, and then to attach to the results the "probable error" which would have been appropriate had the 1000 crabs or the 1000 leaves been drawn at random from the population of interest. Such actions were unwarranted shotgun marriages between the quantitatively unsophisticated idea of sample as "what you get by grabbing a handful" and the mathematical precise notion of a "simple random sample." In the years between we have learned caution by bitter experience. We insist on some semblance of mechanical (dice, coins, random number tables, etc.) randomization before we treat a sample from an existent population as if it were random. We realize that if someone just "grabs a handful," the individuals in the handful almost always resemble one another (on the average) more than do the members of a simple random sample. Even if the "grabs" are randomly spread around so that every individual has an equal chance of entering the sample, there are difficulties. Since the individuals of grab samples resemble one another more than do individuals of random samples, it follows (by a simple mathematical argument) that the means of grab samples resemble one another less than the means of random samples of the same size. From a grab sample, therefore, we tend to underestimate the variability in the population, although we should have to over-estimate it in order to obtain valid estimates of variability of grab sample means by substituting such an estimate into the formula for the variability of means of simple random samples. Thus using simple random sample formulas for grab sample means introduces a double bias, both parts of which lead to an unwarranted appearance of higher stability.

Returning to the crabs, we may suppose that the crabs in which we are interested are all the individuals of a wide-ranging species, spread along a few hundred miles of coast. It is obviously impractical to seek to take a simple random sample from the species - no one knows how to give each crab in the species an equal chance of being drawn into the sample (to say nothing of trying to make these chances independent). But this does not bar us from honestly assessing the likely range of fluctuation of the result. Much effort has been applied in recent years, particularly in sampling human populations, to the development of sampling plans which simultaneously,

(i) are economically feasible
(ii) give reasonably precise results, and
(iii) show within themselves an honest measure of fluctuation of their results.

Any excuse for the dangerous practice of treating non-random samples as random ones is now entirely tenuous. Wider knowledge of the principles involved is needed if scientific investigations involving samples (and what such investigation does not?) are to be solidly based. Additional knowledge of techniques is not so vitally important, though it can lead to substantial economic gains."

2.3 Definition of Terms.

1. Clearance Space - the distances from the top of the first line of intelligence of the address to the top edge of the envelope, and from the bottom of the last line of intelligence of the address to the bottom edge of the envelope.

2. Long letters - any letter equal to or greater than 7 9/16 inches in length.

3. Short letters - any letter less than 7 9/16 inches in length.

4. Regular mail - all first class letter mail that passes over the facing table to be canceled.

5. Air mail - all letter mail given air transportation at the legal rate of six cents per ounce.

6. Metered mail - all first class letter mail bearing a metered imprint. This mail usually arrives at the post office already faced and bundled.

7. Cancel mail - all letters and cards that receive a machine imprint bearing the time and date along with the identity of the originating post office.

8. First Class Hopper - a place in the Washington, D.C. post office where first class mail, which is culled before facing because it cannot be canceled on the regular canceling machines adjacent to the facing tables, is transported by conveyor belt. Here, mail is separated according to its size in preparation for hand cancellation. A very small amount is canceled on a special canceling machine.

9. Cull mail - the remaining collection mail after packages and second class matter have been removed at the culling tables during the initial stage of handling. Hand Cancel and Oversize mail are included in Cull mail.

10. Bulk mail - third class mail which has separately addressed identical pieces bound in bundles as in accordance with Section 134.22 of the Postal Manual.

11. Bundles vs. Letters Each shipment of identical pieces from a given distributor is called a Bundle. Each piece within a Bundle is called a Letter.

12. "Greater than" class - refers to the letters whose height and/or length exceeded the measuring device (7 9/16" x 12 1/16").

13. Oversize class - all Cull mail greater than 5 9/16 inches in height and/or 11 1/16 inches in length.

14. Tolerance limits - predicted limits, determined by the samples, between which at least a certain proportion of a population is predicted to lie. These limits are calculated with a predetermined confidence coefficient.

15. Confidence limits - statistically calculated limits which give an interval estimate within which some population characteristic will lie. These limits are calculated with a predetermined confidence coefficient.

16. Control limits - limits determined from the samples within which successive sample values drawn from the same distribution should fall, using a predetermined probability level.

17. Target population - a class or category of mail for which certain characteristics are to be studied and to which it is intended that the conclusions are to apply. In this report nine classes (i.e., target populations) are defined in order to study outgoing letter size mail.

3. Letter size and color characteristics.

3.1 Introduction. From June 4 to 13, 1956, a statistical sampling study was conducted at the Washington, D. C. post office. A year later, similar studies were conducted at the Los Angeles post office (June 12 to 18, 1957) and the San Francisco post office (June 21 to 28, 1957). Each sampling study was conducted over at least a five day period. The purpose was to determine the size and color characteristics of envelopes for letter size mail originating in each of the cities.

In this report we shall present in several ways the data that were collected during the studies. Each way of presentation is used to bring out one or more particularly important features of the sample data. Included are tables which list the data. Control charts show the uniformity in the sampling methods and make possible visual comparisons between cities and between types of mail. Cumulative percentage graphs further enable comparison of cities to be made. Frequency histograms graphically portray the data and tolerance limits show the predicted sizes between which we can expect at least a certain proportion of a particular type of mail to fall. Section 3.3 on Analysis goes into detail about each topic that is briefly mentioned here.

3.2 Sampling methods and procedures. The procedures and techniques of the statistical sampling plans, which are designed to acquire the appropriate data for determining letter size characteristics, are herein discussed.

To begin with, we must

1. Specify exactly the nature of the populations that are to be studied.
2. Select appropriate sampling points and methods of sampling in which the property of representativeness is inherent.

The nature of post office operations reveals that it would be almost an impossible feat to attempt to select one sampling point or to devise one sampling method to describe all of the letters which pass through a post office. The operations are so diversified and the types of mail handled vary throughout the day so that one composite picture could hardly hope to predict the results for any given situation. For example, Cancel mail, which appears to be the most homogeneous and most easily predictable type, cannot be described in terms of one picture for the whole day because even for this mail the characteristics change throughout the day.

Thus, we choose to define not one but several different populations that when taken together should describe a fairly sizable amount of mail handled in the post office. This report confines itself only to that mail specifically given in the following: (terms are defined on page 13)

1. Cancel Long Regular mail
2. Cancel Long Air mail
3. Cancel Short Regular mail
4. Cancel Short Air mail
5. Metered mail
6. Cull Regular mail
7. Cull Air mail
8. Bulk mail by Bundles
9. Bulk mail by Letters

Below are summarized the number of letters collected in each of the three cities studied for each of the nine populations listed above.

Total Sample Sizes (in pieces)

	San Francisco	Los Angeles	Washington, D.C.	Total
1.	291	581	1253	2125
2.	51	289	222	562
3.	463	800	1545	2808
4.	66	330	248	644
5.	616			616
6.	1133	1924		3057
7.	197	322		519
8.	290*	414*		704*
9.	985,704	1,620,823		2,606,527

* Bundles

3.2.1 <u>Cancel mail</u>. The samples of Cancel mail were taken at the stackers of the cancellation machines at such a time when two or more machines were operating. The mail accumulating in these stackers is fed from a moving conveyor belt that passes seven or eight persons each of whom faces and places on the belt letters selected from those within his reach. Thus the letters undergo a fairly thorough mixing as they are being stacked so that any "bunch" or "bite" of mail sampled at this point would tend to have the property of randomness which is necessary in sampling studies. At a predetermined time one two-inch bite of Long and one two-inch bite of Short letters were drawn from each of the two selected machines making a total of four two-inch bites of mail. Both Long and Short letters were canceled on the same machine but stacked separately in San Francisco and Los Angeles. In Washington, D. C., Long and Short letters were canceled on separate machines. In order to further eliminate the possibility of personal bias, conscious or unconscious, or personal responsibility for actual allocations, a lottery was employed to make a random selection of the two operating machines to be sampled and the samples were always taken at a preselected spot on the stackers.

The only departure from these procedures was made in the drawing of Air mail samples for San Francisco. In San Francisco

Air mail was not separated from the Regular mail until it had been canceled and distributed through the Primary cases. No special effort was made to draw a separate sample of Air mail letters. Instead, it was treated as a part of the Regular mail sample at the canceling machines.

Samples were taken during the period from 10 A.M. to 7 P.M. Although samples were collected throughout this time interval there were two periods of concentration, about 12 noon and near 6 in the evening which corresponded in part with the peak periods in handling outgoing mail.

For San Francisco and Los Angeles the size characteristics were recorded from a metal template used as a measuring device. See Figure 1 . The device has a vertical and horizontal scale marked in quarter inch intervals. A letter was placed on the flat surface and fitted into the ninety degree left hand corner. The scale was visible at the top edge of the left side of the envelope and at the bottom edge of the right side of the envelope. The left hand vertical scale showed the height (to within a quarter of an inch), and the right hand scale showed the length (to within a quarter of an inch). [One should not mistakenly assume that the letter sizes were recorded in units of 1/16 of an inch. Due to some difficulty in reading the measuring device, the inch scale had

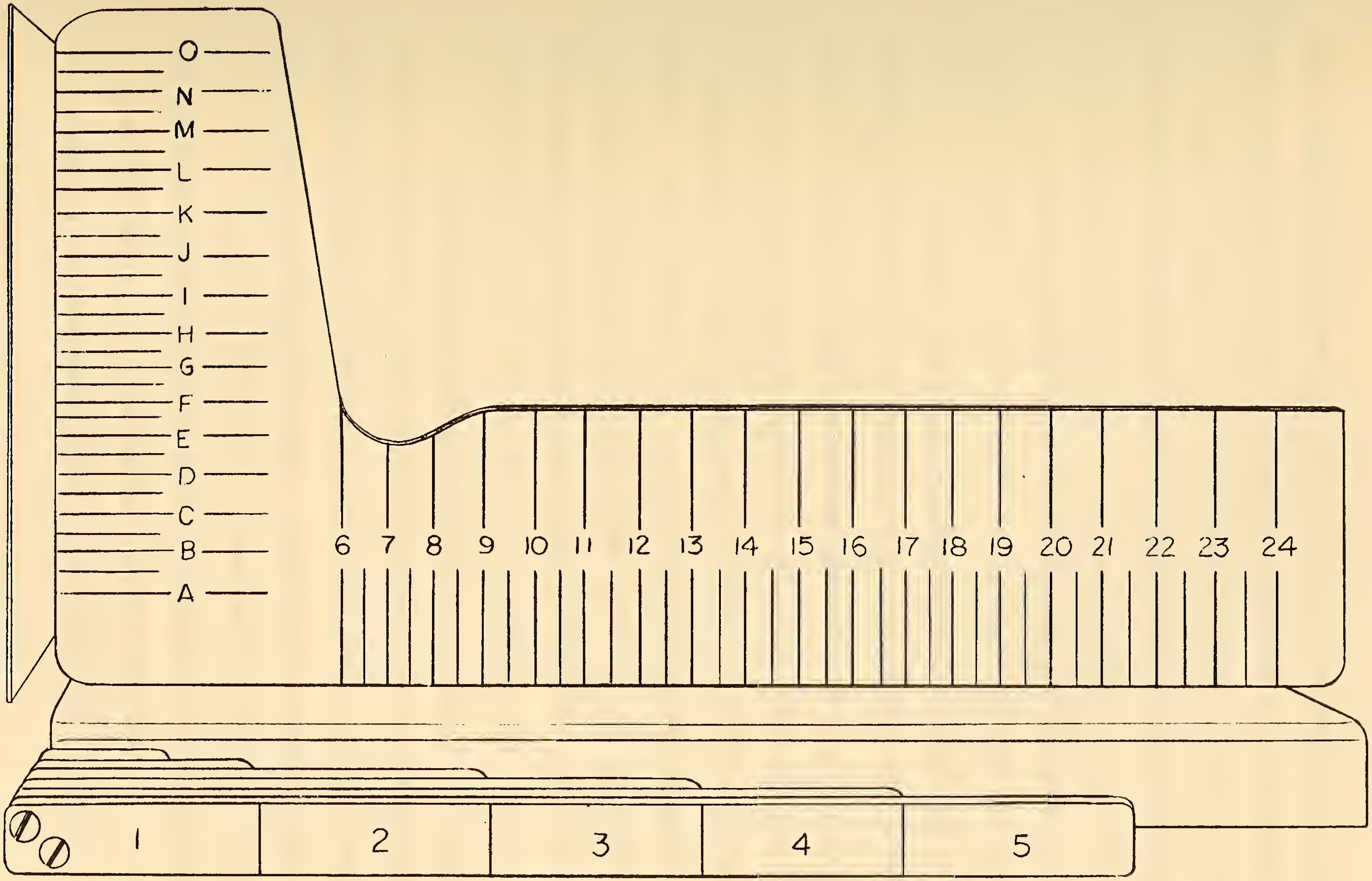


Figure 1 Measuring device for letter-size characteristics. Both the horizontal and vertical scales were coded in order to facilitate the reading and recording of the data. The data were then decoded before being analyzed.

to be read in sixteenths. However, the graduations on the inch scale were spaced at 4/16 of an inch so that the scale was "read" to 1/4 inch.] A protruding edge at the front base of the device measured the thickness in 1/8 inch intervals. Thus, each letter was measured for height, length, and thickness. In addition, a fourth characteristic, the color of the envelope, was recorded.

For Washington, D.C. a procedure similar to that described above was used with the exception that the height and length dimensions were recorded to within 1/2 inch intervals, as compared to 1/4 inch intervals for San Francisco and Los Angeles. The color characteristic was not recorded for Washington, D. C.

3.2.2 Metered mail. The samples of Metered mail were taken from trays in the metered section at such a time when two or more areas were operating. Metered mail is usually already faced and therefore does not undergo the mixing process characteristic of the Cancel mail at the facing table. Furthermore Metered mail tends to "run", that is, entire clusters of mail would have many of the same destination and size characteristics. Therefore a "bite" or "bunch" of Metered mail would not have the required property of randomness. What was done was to select, from the surface tier of mail stacked in trays on a cart, successive letters every two inches apart until approximately two inches of letters were obtained. Again a lottery was employed to make a random selection of the two areas to be sampled and the sampling was always started at a preselected spot on the tier.

3.2.3 Cull mail. Before letter mail reaches the facing tables, a preliminary and rough separation is made. This initial separation process is called culling. In the three post offices studied in this report, this activity is carried out on the mezzanine above the facing tables. Sacks of collection mail are emptied on culling tables and various types of mail, such as second and third class, parcel post, meter, and all other mail given special handling (undersize and oversize pieces are in this group) are removed. The remainder is processed on the facing tables below.

A knowledge of the distribution of mail (whatever the classification) at this point in the processing stage would provide information about a much larger class of mail than studied at the facing table. Reported here is a sampling study carried out directly at the culling table. The results, while informative and unbiased, in that the methods provide good estimates of the averages, are subject to more variability than is evidenced in the Cancel mail study.

Cull mail samples were selected in the following manner. At a predetermined time, three bags of outgoing mail were chosen at random and emptied on a clean table. The packages and second class mail were removed and the remainder thoroughly mixed by hand. A plan for drawing samples from the remainder is representative of a general picture of first class mail, air mail, and flats during the first stages in the handling of outgoing mail. After the pile was thoroughly mixed, the sampler reached into it and pulled out about fifty pieces of mail (about one to three handfuls). Each letter was measured for its height, length, thickness, and the color was recorded as was described in the previous discussion for Cancel mail.

But, one might ask, "Is this a good method of selecting a subsample from the three bags of mail?" A ready answer was obtained as follows:

Three bags of outgoing mail were selected at random and a complete enumeration was made of the combined contents for the five categories of mail: Long Regular, Short Regular, Long Air, Short Air, and Flats. The respective proportions were calculated.

Then the combined contents of the three bags were thoroughly mixed and a sampler pulled out about fifty letters (one to three handfuls). These results and their respective proportions were calculated. Comparing the proportions obtained by the two procedures showed that they were much more in agreement than was first suspected. This comparison was made on the spot.

3.2.4 Bulk mail. All Bulk mail that accumulated at the post office within the approximate time period, 10 A.M. and 7 P.M., was considered in the sample. As each Bundle of Bulk mail arrived, one Letter was removed and the total number of Letters within the Bundle was estimated according to the standard procedure by weighing the corresponding Bundle. The Letter that had been removed was set aside with the information about the total number of Letters within the Bundle. Later, the Letters which had been removed from Bundles and allowed to accumulate, were measured for height, length, and thickness according to the procedure discussed under Cancel mail. [Actually, this type of mail was not sampled statistically because no random selection of letters was made. A partial complete enumeration, which included all Bulk mail within a certain time interval, was made. This is one instance where a complete enumeration was simpler than resorting to a statistical sampling plan.]

3.3 Analysis

3.3.1. Length, height, and thickness characteristics

a) Presentation of data. Length, height, and thickness are three variables of interest in this study. The data for each variable for Los Angeles, San Francisco, and Washington, D. C. are presented in Tables 2 to 21 . Each table gives the frequency corresponding to the indicated class interval. Some of the tables also present the relative frequency of each class interval, i.e., the ratio of the number of pieces in the class interval to the total sample. Other tables give the cumulative percentage for each class interval, i.e., the sum of all percentages for all class intervals up to and including the one in question.

We shall have occasion to use the term sample distribution, by which we mean the classification according to one of the letter size characteristics of all the sample data in one city and for one type of mail. For example, all the data from Cancel Short Air mail for Los Angeles when classified according to Length, is considered a sample distribution. Table 3 has the data for the example that has just been cited, Cancel Short Air mail for Los Angeles by Length. The column headed frequency shows the number of letters whose lengths fall in the corresponding interval of measurement. The column headed cumulative percentage shows the sum of all

TABLE 2

Frequency (f) and cumulative percentage (%) by designated Height of Cancel Short Regular and Cancel Short Air mail at S.F. and L.A.

Interval in Inches	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
1 13/16 to 2 1/16								
2 1/16 to 2 5/16					2	.3		
2 5/16 to 2 9/16								
2 9/16 to 2 13/16					1	.4		
2 13/16 to 3 1/16	5	1.1			23	3.3	3	.9
3 1/16 to 3 5/16	93	21.2			65	11.4	7	3.0
3 5/16 to 3 9/16	83	39.1	11	16.7	141	29.0	33	13.0
3 9/16 to 3 13/16	228	88.3	36	71.2	407	79.9	167	63.6
3 13/16 to 4 1/16	35	95.9	13	90.9	45	85.5	43	76.7
4 1/16 to 4 5/16	10	98.1	3	95.5	46	91.3	28	85.2
4 5/16 to 4 9/16	3	98.7	3	100.0%	13	92.9	11	88.5
4 9/16 to 4 13/16	4	99.6			29	96.5	17	93.6
4 13/16 to 5 1/16	2	100.0%			15	98.4	7	95.8
5 1/16 to 5 5/16					6	99.1	10	98.8
5 5/16 to 5 9/16							2	99.4
5 9/16 to 5 13/16					3	99.5	2	100.0%
5 13/16 to 6 1/16								
6 1/16 to 6 5/16					2	99.8		
6 5/16 to 6 9/16					2	100.0%		
6 9/16 to 6 13/16								
6 13/16 to 7 1/16								
7 1/16 to 7 5/16								
7 5/16 to 7 9/16								
> 7 9/16								
Total Sample Size	463		66		800		330	

TABLE 3

Frequency (f) and cumulative percentage (%) by designated Length of Cancel Short Regular and Cancel Short Air mail at S.F. and L.A.

Interval in Inches	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
< 3 13/16					8	1.0		
3 13/16 to 4 1/16					3	1.4	1	.3
4 1/16 to 4 5/16	1	.2			19	3.8		
4 5/16 to 4 9/16					2	4.0		
4 9/16 to 4 13/16	3	.9			4	4.5	1	.6
4 13/16 to 5 1/16	5	1.9			15	6.4	4	1.8
5 1/16 to 5 5/16	7	3.5	1	1.5	10	7.6	9	4.5
5 5/16 to 5 9/16	127	30.9	7	12.1	79	17.5	16	9.4
5 9/16 to 5 13/16	15	34.1	3	16.7	19	19.9	28	17.9
5 13/16 to 6 1/16	30	40.6	8	28.8	79	29.8	39	29.7
6 1/16 to 6 5/16	19	44.7	4	34.8	85	40.4	30	38.8
6 5/16 to 6 9/16	174	82.3	30	80.3	349	84.0	141	81.5
6 9/16 to 6 13/16	46	92.2	2	83.3	59	91.4	14	85.8
6 13/16 to 7 1/16	1	92.4	3	87.9	12	92.9	14	90.0
7 1/16 to 7 5/16	8	94.2			13	94.5	4	91.2
7 5/16 to 7 9/16	27	100.0%	8	100.0%	44	100.0%	29	100.0%
Total Sample Size	463		66		800		330	

TABLE 4

Frequency (f) and cumulative percentage (%) by designated Height of Cancel Long Regular and Cancel Long Air mail at S.F. and L.A.

Interval in Inches	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
1 13/16 to 2 1/16								
2 1/16 to 2 5/16								
2 5/16 to 2 9/16								
2 9/16 to 2 13/16								
2 13/16 to 3 1/16								
3 1/16 to 3 5/16			1	2.0				
3 5/16 to 3 9/16	4	1.4	1	3.9	4	.7	1	.3
3 9/16 to 3 13/16	8	4.1	2	7.8	18	3.8	9	3.5
3 13/16 to 4 1/16	45	19.6	3	13.7	99	20.8	26	12.5
4 1/16 to 4 5/16	228	97.9	39	90.2	451	98.5	246	97.6
4 5/16 to 4 9/16	6	100.0%	5	100.0%	8	99.8	6	99.7
4 9/16 to 4 13/16								
4 13/16 to 5 1/16					1	100.0%		
5 1/16 to 5 5/16								
5 5/16 to 5 9/16							1	100.0%
5 9/16 to 5 13/16								
5 13/16 to 6 1/16								
6 1/16 to 6 5/16								
6 5/16 to 6 9/16								
6 9/16 to 6 13/16								
6 13/16 to 7 1/16								
7 1/16 to 7 5/16								
7 5/16 to 7 9/16								
> 7 9/16								
Total Sample Size	291		51		581		289	

TABLE 5

Frequency (f) and cumulative percentage (%) by designated Length of Cancel Long Regular and Cancel Long Air mail at S.F. and L.A.

Interval in Inches	San Francisco Regular f	%	San Francisco Air Mail f	%	Los Angeles Regular f	%	Los Angeles Air Mail f	%
7 9/16 to 7 13/16	4	1.4			3	.5		
7 13/16 to 8 1/16							1	.3
8 1/16 to 8 5/16	5	3.1			6	1.5	9	3.5
8 5/16 to 8 9/16	2	3.8			2	1.9	3	4.5
8 9/16 to 8 13/16	3	4.8	1	2.0	8	3.3	6	6.6
8 13/16 to 9 1/16	45	20.3	4	9.8	92	19.1	21	13.8
9 1/16 to 9 5/16								
9 5/16 to 9 9/16	228	98.6	45	98.0	463	98.8	245	98.6
9 9/16 to 9 13/16					1	99.0		
9 13/16 to 10 1/16							1	99.0
10 1/16 to 10 5/16								
10 5/16 to 10 9/16	4	100.0%			4	99.7	3	100.0%
10 9/16 to 1013/16			1	100.0%				
10 13/16 to 11 1/16								
11 1/16 to 11 5/16					1	99.8		
11 5/16 to 11 9/16					1	100.0%		
11 9/16 to 1113/16								
11 13/16 to 11 1/16								
> 12 1/16								
Total Sample Size	291		51		581		289	

TABLE 6

Frequency (f) and cumulative percentage (%) by designated Height of Cancel Short and Cancel Long mail at D.C.

Interval in Inches	Short Letters			
	Regular		Air Mail	
	f	%	f	%
2 1/16 to 2 9/16				
2 9/16 to 3 1/16	25	1.6	3	1.2
3 1/16 to 3 9/16	565	38.2	53	22.6
3 9/16 to 4 1/16	766	87.8	151	83.5
4 1/16 to 4 9/16	120	95.5	29	95.2
4 9/16 to 5 1/16	59	99.4	11	99.6
5 1/16 to 5 9/16	10	100.0%	1	100.0%
Total Sample Size	1545		248	

Interval in Inches	Long Letters			
	Regular		Air Mail	
	f	%	f	%
2 1/16 to 2 9/16				
2 9/16 to 3 1/16			1	0.5
3 1/16 to 3 9/16	8	0.6	4	2.3
3 9/16 to 4 1/16	290	23.8	34	17.6
4 1/16 to 4 9/16	947	99.4	182	99.5
4 9/16 to 5 1/16	6	99.8		99.5
5 1/16 to 5 9/16	2	100.0%	1	100.0%
Total Sample Size	1253		222	

TABLE 7

Frequency (f) and cumulative percentage (%) by designated Length of Cancel Short and Cancel Long mail at D.C.

Interval in Inches	Short Letters				Long Letters			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
3 9/16 to 4 1/16	2	0.1						
4 1/16 to 4 9/16	28	1.9						
4 9/16 to 5 1/16	36	4.3	8	3.2				
5 1/16 to 5 9/16	451	33.5	57	26.2				
5 9/16 to 6 1/16	251	49.7	33	39.5				
6 1/16 to 6 9/16	503	82.3	112	84.7				
6 9/16 to 7 1/16	169	93.2	11	89.1				
7 1/16 to 7 9/16	105	100.0%	27	100.0%				
Total Sample Size	1545		248					
7 9/16 to 8 1/16					6	0.5	4	1.8
8 1/16 to 8 9/16					22	2.2	2	2.7
8 9/16 to 9 1/16					257	22.7	34	18.0
9 1/16 to 9 9/16					947	98.3	177	97.7
9 9/16 to 10 1/16					3	98.6	3	99.1
10 1/16 to 10 9/16					13	99.6	2	100.0%
10 9/16 to 11 1/16					4	99.9		
11 1/16 to 11 9/16						99.9		
11 9/16 to 12 1/16					1	100.0%		
Total Sample Size					1253		222	

TABLE 8

Frequency (f) and cumulative percentage (%) by designated Thickness of Cancel Short Regular and Cancel Short Air mail at S.F. and L.A.

Interval in Inches	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
0 to 1/8	436	94.2	53	80.3	762	95.3	297	90.0
1/8 to 2/8	23	99.1	13	100.0%	36	99.8	32	99.7
2/8 to 3/8	3	99.8			2	100.0%	1	100.0%
3/8 to 4/8	1	100.0%						
4/8 to 5/8								
Total Sample Size	463		66		800		330	

TABLE 9

Frequency (f) and cumulative percentage (%) by designated Thickness of Cancel Long Regular and Cancel Long Air mail at S.F. and L.A.

Interval in Inches	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
0 to 1/8	252	86.6	34	66.7	528	90.9	252	87.2
1/8 to 2/8	26	95.5	11	88.2	51	99.7	32	98.3
2/8 to 3/8	11	99.3	6	100.0%	2	100.0%	5	100.0%
3/8 to 4/8	2	100.0%						
4/8 to 5/8								
Total Sample Size	291		51		581		289	

TABLE 10

Frequency (f) and cumulative percentage (%) by designated Thickness of Cancel Short and Cancel Long mail at D. C.

Washington, D. C.

Interval in inches	Short Letters				Long Letters			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
0 to 1/8	1405	90.9	224	90.3	1060	84.6	184	82.9
1/8 to 2/8	127	99.2	22	99.2	158	97.2	32	97.3
2/8 to 3/8	12	99.9	2	100.0%	31	99.7	6	100.0%
3/8 to 4/8	1	100.0%			4	100.0%		
Total Sample Size	1545		248		1253		222	

TABLE 11

Frequency (f), relative frequency (r.f.), and cumulative percentage (%) by designated Height of Metered mail at S.F.

Interval in Inches	San Francisco f	r.f.	%
< 1 13/16			
1 13/16 to 2 1/16			
2 1/16 to 2 5/16			
2 5/16 to 2 9/16			
2 9/16 to 2 13/16			
2 13/16 to 3 1/16	2	.00	0.3
3 1/16 to 3 5/16	15	.02	2.8
3 5/16 to 3 9/16	105	.17	19.8
3 9/16 to 3 13/16	182	.30	49.4
3 13/16 to 4 1/16	121	.20	69.0
4 1/16 to 4 5/16	160	.26	95.0
4 5/16 to 4 9/16	23	.04	98.7
4 9/16 to 4 13/16	4	.01	99.4
4 13/16 to 5 1/16	2	.00	99.7
5 1/16 to 5 5/16	1	.00	99.8
5 5/16 to 5 9/16			
5 9/16 to 5 13/16	1	.00	100.0%
5 13/16 to 6 1/16			
6 1/16 to 6 5/16			
6 5/16 to 6 9/16			
6 9/16 to 6 13/16			
6 13/16 to 7 1/16			
7 1/16 to 7 5/16			
7 5/16 to 7 9/16			
> 7 9/16			
Total Sample Size	616	1.00	

Table 12

Frequency (f), relative frequency (r.f.), and cumulative percentage (%) by designated Thickness of Metered mail at S.F.

Interval in Inches	San Francisco f	r.f.	%
0 to 1/8	501	.81	81.3
1/8 to 2/8	47	.08	89.0
2/8 to 3/8	51	.08	97.2
3/8 to 4/8	11	.02	99.0
4/8 to 5/8	2	.00	99.4
> 5/8	4	.01	100.0%
Total Sample Size	616	1.00	

TABLE 13

Frequency (f), relative frequency (r.f.), and cumulative percentage (%) by designated Length of Metered mail at S.F.

Interval in Inches	San Francisco		
	f	r.f.	%
3 13/16 to 4 1/16			
4 1/16 to 4 5/16			
4 5/16 to 4 9/16			
4 9/16 to 4 13/16			
4 13/16 to 5 1/16	2	.00	0.3
5 1/16 to 5 5/16			
5 5/16 to 5 9/16	16	.03	2.9
5 9/16 to 5 13/16			
5 13/16 to 6 1/16	5	.01	3.7
6 1/16 to 6 5/16			
6 5/16 to 6 9/16	72	.12	15.4
6 9/16 to 6 13/16	151	.25	39.9
6 13/16 to 7 1/16	1	.00	40.1
7 1/16 to 7 5/16	2	.00	40.4
7 5/16 to 7 9/16	4	.01	41.1
7 9/16 to 7 13/16	145	.24	64.6
7 13/16 to 8 1/16	6	.01	65.6
8 1/16 to 8 5/16	1	.00	65.7
8 5/16 to 8 9/16	1	.00	65.9
8 9/16 to 8 13/16	4	.01	66.6
8 13/16 to 9 1/16	22	.04	70.1
9 1/16 to 9 5/16	1	.00	70.3
9 5/16 to 9 9/16	170	.28	97.9
9 9/16 to 9 13/16			
9 13/16 to 10 1/16	2	.00	98.2
10 1/16 to 10 5/16			
10 5/16 to 10 9/16	8	.01	99.5
10 9/16 to 10 13/16			
10 13/16 to 11 1/16	2	.00	99.8
11 1/16 to 11 5/16			
11 5/16 to 11 9/16	1	.00	100.0%
11 9/16 to 11 13/16			
11 13/16 to 12 1/16			
> 12 1/16			
Total Sample Size	616	1.01	

TABLE 14

Frequency (f) and cumulative percentage (%) by designated Height of Cull Regular and Cull Air mail from S.F. and L.A.

Interval in Inches	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
	f	%	f	%	f	%	f	%
1 13/16 to 2 1/16								
2 1/16 to 2 5/16					1	.1		
2 5/16 to 2 9/16								
2 9/16 to 2 13/16	20	1.8			7	.4		
2 13/16 to 3 1/16	9	2.6			12	1.0		
3 1/16 to 3 5/16	78	9.4	1	.5	80	5.2	1	.3
3 5/16 to 3 9/16	127	20.7	9	5.1	220	16.6	18	5.9
3 9/16 to 3 13/16	253	43.0	74	42.6	454	40.2	114	41.3
3 13/16 to 4 1/16	113	53.0	25	55.3	238	52.6	34	51.9
4 1/16 to 4 5/16	459	93.5	72	91.9	712	89.6	105	84.5
4 5/16 to 4 9/16	13	94.6	6	94.9	28	91.1	7	86.6
4 9/16 to 4 13/16	7	95.2			29	92.6	10	89.8
4 13/16 to 5 1/16	11	96.2	1	95.4	16	93.4	9	92.5
5 1/16 to 5 5/16	3	96.5	1	95.9	6	93.7	2	93.2
5 5/16 to 5 9/16	5	96.9					2	93.8
5 9/16 to 5 13/16			1	96.4	1	93.8	4	95.0
5 13/16 to 6 1/16	3	97.2	1	97.0	5	94.0		
6 1/16 to 6 5/16								
6 5/16 to 6 9/16			1	97.5	10	94.5		
6 9/16 to 6 13/16								
6 13/16 to 7 1/16					2	94.6		
7 1/16 to 7 5/16								
7 5/16 to 7 9/16	1	97.3			18	95.6	2	95.7
> 7 9/16	31	100.0%	5	100.0%	85	100.0%	14	100.0%
Total Sample Size	1133		197		1924		322	

Frequency (f) and cumulative percentage (%) by designated Length of Cull Regular and Cull Air mail at S.F. and L.A.

	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
Interval in Inches	f	%	f	%	f	%	f	%
< 3 13/16	5	.4			1	.1		
3 13/16 to 4 1/16					1	.1		
4 1/16 to 4 5/16	6	1.0			6	.4		
4 5/16 to 4 9/16	1	1.1			5	.7		
4 9/16 to 4 13/16	5	1.5	1	.5	5	.9		
4 13/16 to 5 1/16	12	2.6			23	2.1	3	.9
5 1/16 to 5 5/16	36	5.7	4	2.5	26	3.5	6	2.8
5 5/16 to 5 9/16	125	16.8	8	6.6	109	9.1	12	6.5
5 9/16 to 5 13/16	14	18.0	8	10.7	20	10.2	11	9.9
5 13/16 to 6 1/16	51	22.5	7	14.2	110	15.9	15	14.6
6 1/16 to 6 5/16	26	24.8	8	18.3	89	20.5	14	18.9
6 5/16 to 6 9/16	204	42.8	67	52.3	367	39.6	100	50.0
6 9/16 to 6 13/16	35	45.9	3	53.8	57	42.6	14	54.3
6 13/16 to 7 1/16					13	43.2	2	55.0
7 1/16 to 7 5/16	6	46.4	1	54.3	33	45.0	1	55.3
7 5/16 to 7 9/16	48	50.7	15	61.9	145	52.5	19	61.2
7 9/16 to 7 13/16	4	51.0	1	62.4	19	53.5		
7 13/16 to 8 1/16	4	51.4			3	53.6		
8 1/16 to 8 5/16	4	51.7			5	53.9	4	62.4
8 5/16 to 8 9/16	2	51.9	1	62.9	8	54.3	1	62.7
8 9/16 to 8 13/16	18	53.5			8	54.7		
8 13/16 to 9 1/16	52	58.1	1	63.5	81	58.9	5	64.3
9 1/16 to 9 5/16					1	59.0	15	68.9
9 5/16 to 9 9/16	439	96.8	65	96.4	673	94.0	74	91.9
9 9/16 to 9 13/16	1	96.9	1	97.0				
9 13/16 to 10 1/16	1	97.0			6	94.3	5	93.5
10 1/16 to 10 5/16							1	93.8
10 5/16 to 10 9/16	8	97.7			23	95.5	3	94.7
10 9/16 to 10 13/16					1	95.5		
10 13/16 to 11 1/16	4	98.1			3	95.7	2	95.3
11 1/16 to 11 5/16								
11 5/16 to 11 9/16			1	97.5	3	95.8	1	95.7
11 9/16 to 11 13/16	1	98.1			2	95.9		
11 13/16 to 12 1/16	18	99.7	4	99.5	31	97.6	7	97.8
> 12 1/16	3	100.0%	1	100.0%	47	100.0%	7	100.0%
Total Sample Size	1133		197		1924		322	

TABLE 16

Frequency (f) and cumulative percentage (%) by designated Height of Bulk mail by Bundles at S.F. and L.A.

Interval in Inches	San Francisco		Los Angeles	
	f	%	f	%
1 13/16 to 2 1/16	1	.3		
2 1/16 to 2 5/16				
2 5/16 to 2 9/16				
2 9/16 to 2 13/16			7	1.7
2 13/16 to 3 1/16	1	.7	4	2.7
3 1/16 to 3 5/16	11	4.5	26	8.9
3 5/16 to 3 9/16	24	12.8	29	15.9
3 9/16 to 3 13/16	40	26.6	66	31.9
3 13/16 to 4 1/16	28	36.2	35	40.3
4 1/16 to 4 5/16	94	68.6	87	61.4
4 5/16 to 4 9/16	7	71.0	8	63.3
4 9/16 to 4 13/16	10	74.5	8	65.2
4 13/16 to 5 1/16	6	76.6	6	66.7
5 1/16 to 5 5/16	4	77.9	3	67.4
5 5/16 to 5 9/16	15	83.1	20	72.2
5 9/16 to 5 13/16	3	84.1	5	73.4
5 13/16 to 6 1/16	6	86.2	17	77.5
6 1/16 to 6 5/16			1	77.8
6 5/16 to 6 9/16	7	88.6	8	79.7
6 9/16 to 6 13/16			1	80.0
6 13/16 to 7 1/16	1	89.0	5	81.2
7 1/16 to 7 5/16	1	89.3	2	81.6
7 5/16 to 7 9/16	1	89.7	6	83.1
> 7 9/16	30	100.0%	70	100.0%
Total Sample Size	290		414	

TABLE 17

Frequency (f) and cumulative percentage (%) by designated Length of Bulk mail by Bundles at S.F. and L.A.

Interval in Inches	San Francisco		Los Angeles	
	f	%	f	%
3 13/16 to 4 1/16	1	.3	3	.7
4 1/16 to 4 5/16	1	.7	1	1.0
4 5/16 to 4 9/16				
4 9/16 to 4 13/16				
4 13/16 to 5 1/16	1	1.0		
5 1/16 to 5 5/16	2	1.7	2	1.4
5 5/16 to 5 9/16	21	9.0	42	11.6
5 9/16 to 5 13/16	2	9.7	4	12.6
5 13/16 to 6 1/16	6	11.7	9	14.7
6 1/16 to 6 5/16	4	13.1	10	17.1
6 5/16 to 6 9/16	14	17.9	20	22.0
6 9/16 to 6 13/16	3	19.0	10	24.4
6 13/16 to 7 1/16	12	23.1	6	25.8
7 1/16 to 7 5/16			1	26.1
7 5/16 to 7 9/16	9	26.2	10	28.5
7 9/16 to 7 13/16	2	26.9		
7 13/16 to 8 1/16	4	28.3	14	31.9
8 1/16 to 8 5/16	6	30.3	6	33.3
8 5/16 to 8 9/16	39	43.8	50	45.4
8 9/16 to 8 13/16	17	49.7	9	47.6
8 13/16 to 9 1/16	23	57.6	27	54.1
9 1/16 to 9 5/16	2	58.3	6	55.6
9 5/16 to 9 9/16	88	88.6	93	78.0
9 9/16 to 9 13/16	4	90.0	2	78.5
9 13/16 to 10 1/16			4	79.5
10 1/16 to 10 5/16			2	80.0
10 5/16 to 10 9/16	1	90.3	5	81.2
10 9/16 to 10 13/16	1	90.7	9	83.3
10 13/16 to 11 1/16	4	92.1	24	89.1
11 1/16 to 11 5/16	4	93.4	6	90.6
11 5/16 to 11 9/16			15	94.2
11 9/16 to 11 13/16	2	94.1	3	94.9
11 13/16 to 12 1/16	13	98.6	18	99.3
> 12 1/16	4	100.0%	3	100.0%
Total Sample Size	290		414	

TABLE 18

Frequency (f) and cumulative percentage (%) by designated Height of Bulk mail by Letters at S.F. and L.A.

Interval in Inches	San Francisco		Los Angeles	
	f	%	f	%
1 13/16 to 2 1/16	365	0.0		
2 1/16 to 2 5/16				
2 5/16 to 2 9/16				
2 9/16 to 2 13/16			37088	2.3
2 13/16 to 3 1/16	369	0.1	5591	2.6
3 1/16 to 3 5/16	17065	1.8	44523	5.4
3 5/16 to 3 9/16	114390	13.4	81392	10.4
3 9/16 to 3 13/16	71110	20.6	490543	40.7
3 13/16 to 4 1/16	275572	48.6	132360	48.8
4 1/16 to 4 5/16	288499	77.8	193373	60.8
4 5/16 to 4 9/16	17547	79.6	4025	61.0
4 9/16 to 4 13/16	31386	82.8	11412	61.7
4 13/16 to 5 1/16	10786	83.9	14884	62.6
5 1/16 to 5 5/16	16573	85.6	18415	63.8
5 5/16 to 5 9/16	51036	90.8	138609	72.3
5 9/16 to 5 13/16	6643	91.4	5571	72.7
5 13/16 to 6 1/16	7269	92.2	46351	75.5
6 1/16 to 6 5/16			5000	75.8
6 5/16 to 6 9/16	15680	93.8	6360	76.2
6 9/16 to 6 13/16			200	76.2
6 13/16 to 7 1/16	1338	93.9	2884	76.4
7 1/16 to 7 5/16	1409	94.0	4958	76.7
7 5/16 to 7 9/16	3386	94.4	19787	77.9
> 7 9/16	55281	100.0%	357497	100.0%
Total Sample Size	985704		1620823	

TABLE 19

Frequency (f) and cumulative percentage (%) by designated Length of Bulk mail by Letters at S.F. and L.A.

Interval in Inches	San Francisco		Los Angeles	
	f	%	f	%
3 13/16 to 4 1/16	365	0.0	18621	1.1
4 1/16 to 4 5/16	410	0.1	7680	1.6
4 5/16 to 4 9/16				
4 9/16 to 4 13/16				
4 13/16 to 5 1/16	369	0.1		
5 1/16 to 5 5/16	6496	0.8	16202	2.6
5 5/16 to 5 9/16	87550	9.7	77124	7.4
5 9/16 to 5 13/16	1342	9.8	16377	8.4
5 13/16 to 6 1/16	13409	11.2	10802	9.1
6 1/16 to 6 5/16	3221	11.5	21822	10.4
6 5/16 to 6 9/16	47756	16.3	103313	16.8
6 9/16 to 6 13/16	1092	16.4	94660	22.6
6 13/16 to 7 1/16	17635	18.2	30627	24.5
7 1/16 to 7 5/16			293	24.5
7 5/16 to 7 9/16	28546	21.1	24175	26.0
7 9/16 to 7 13/16	73694	28.6		
7 13/16 to 8 1/16	4429	29.0	160340	35.9
8 1/16 to 8 5/16	20863	31.2	10061	36.5
8 5/16 to 8 9/16	145011	45.9	139428	45.1
8 9/16 to 8 13/16	121948	58.2	79272	50.0
8 13/16 to 9 1/16	130774	71.5	120669	57.5
9 1/16 to 9 5/16	2630	71.8	23242	58.9
9 5/16 to 9 9/16	223503	94.5	271516	75.7
9 9/16 to 9 13/16	5524	95.0	700	75.7
9 13/16 to 10 1/16			3877	75.9
10 1/16 to 10 5/16			726	76.0
10 5/16 to 10 9/16	55	95.0	13156	76.8
10 9/16 to 10 13/16	117	95.0	56433	80.3
10 13/16 to 11 1/16	9383	96.0	155772	89.9
11 1/16 to 11 5/16	17515	97.8	14055	90.8
11 5/16 to 11 9/16			65670	94.8
11 9/16 to 11 13/16	2900	98.1	34006	96.9
11 13/16 to 12 1/16	13039	99.4	38454	99.3
> 12 1/16	6128	100.0%	11750	100.0%
Total Sample Size	985704		1620823	

TABLE 20

Frequency (f) and cumulative percentage (%) by designated Thickness of Cull Regular and Cull Air mail at S.F. and L.A.

	San Francisco				Los Angeles			
	Regular		Air Mail		Regular		Air Mail	
Interval in Inches	f	%	f	%	f	%	f	%
0 to 1/8	883	77.9	164	83.2	1730	89.9	285	88.5
1/8 to 2/8	186	94.4	18	92.4	118	96.0	23	95.7
2/8 to 3/8	32	97.2	9	97.0	45	98.4	5	97.2
3/8 to 4/8	14	98.4	5	99.5	14	99.1	1	97.5
4/8 to 5/8	7	99.0			6	99.4	3	98.4
> 5/8	11	100.0%	1	100.0%	11	100.0%	5	100.0%
Total Sample Size	1133		197		1924		322	

TABLE 21

Frequency (f) and cumulative percentage (%) by designated Thickness of Bulk mail by Bundles and Bulk mail by Letters at S.F. and L.A.

	Bundles				Letters			
	San Fran.		Los Angeles		San Fran.		Los Angeles	
Interval in Inches	f	%	f	%	f	%	f	%
0 to 1/8	251	86.6	366	88.4	921084	93.4	1483392	91.5
1/8 to 2/8	25	95.2	28	95.2	54223	98.9	105900	98.1
2/8 to 3/8	5	96.9	11	97.8	5235	99.5	17737	99.1
3/8 to 4/8	3	97.9	2	98.3	2578	99.7	1046	99.2
4/8 to 5/8	1	98.3	4	99.3	1338	99.9	9950	99.8
> 5/8	5	100.0%	3	100.0%	1246	100.0%	2798	100.0%
Total Sample Size	290		414		985704		1620823	

percentages for all class intervals up to and including the one in question. There was one letter whose length fell in the interval 3 13/16 to 4 1/16 inches and this represented .3% of the total sample, 330 letters. There were four letters whose length measured between 4 13/16 and 5 1/16 inches and this, along with the two previous letters, comprised 1.8% of the total sample.

From this manner of presenting the data, we are able to see how much of the sample was greater or less than a certain interval.

All of the data presented in Tables 2 to 21 include post cards and all the analyses have been made with these post cards included. Table 22 shows the number and percentage of post cards in the samples.

Control charts for averages $\bar{x}$ have been included in this report to show the consistency of averages of the samples with regard to height and length. An average height and an average length have been calculated for each sample that was collected during the study. By combining all the averages of samples collected for a particular type of mail, an overall average $\bar{\bar{x}}$ was calculated pertaining to each type. For example, during the Los Angeles study, eleven samples were collected of Cancel Short Air mail. The average sample size n was 30. Altogether there were 330 letters in the total

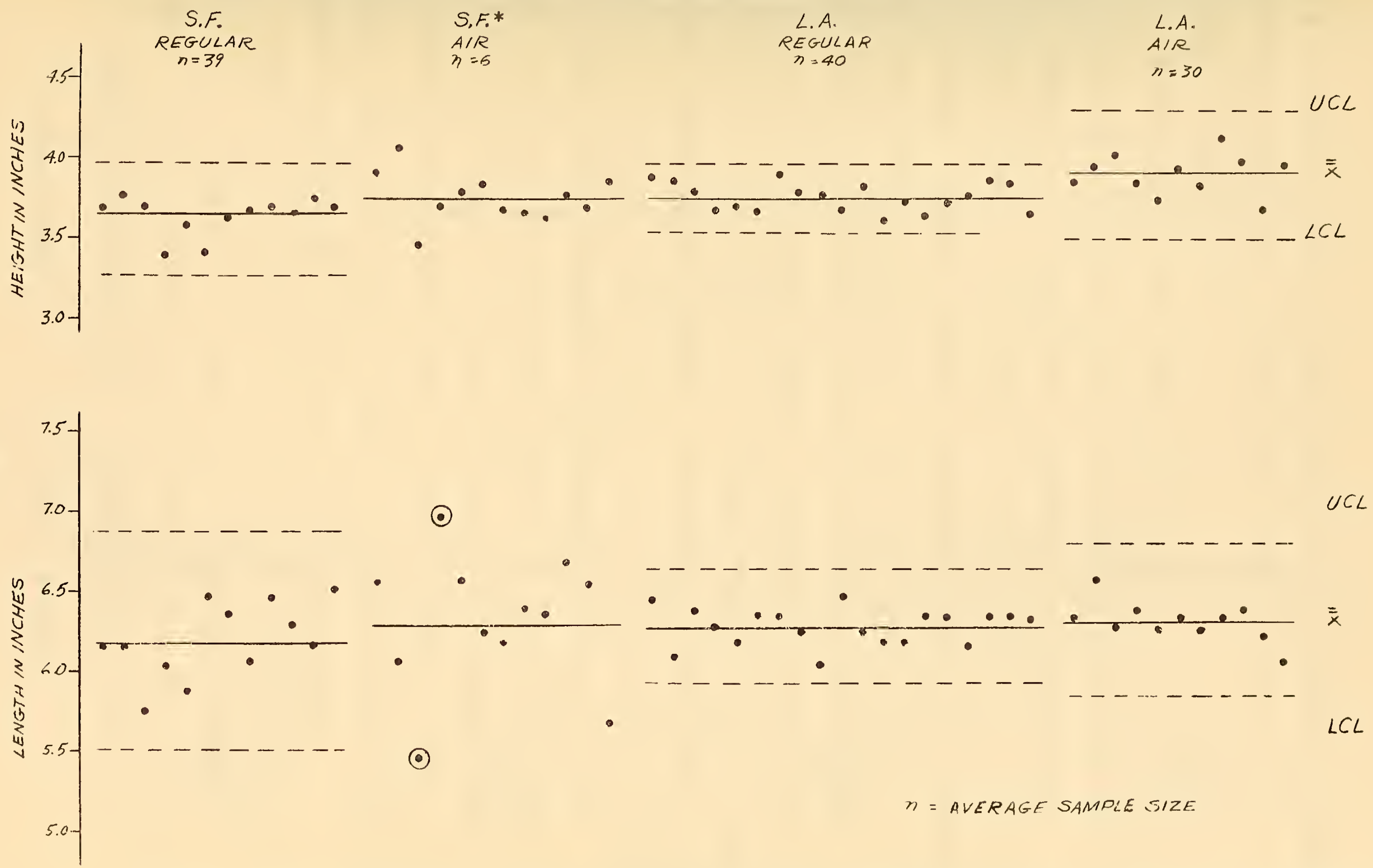
TABLE 22 Number and percentage of Post Cards at S.F., L.A., and D.C.

	San Francisco			Los Angeles			Washington, D. C.		
	Total Sample	No. Cards	% Cards	Total Sample	No. Cards	% Cards	Total Sample	No. Cards	% Cards
Cancel Mail									
Air	117	8	6.8	619	15	2.4	470	36	7.7
Regular	754	64	8.5	1381	119	8.6	2798	408	14.6
Cull Mail									
Air	197	5	2.5	322	17	5.3			
Regular	1133	70	6.2	1924	59	3.1			
Metered Mail	616	18	2.9						

sample. The average heights $\bar{x}$ in inches, from each of the eleven samples were 3.86, 3.94, 4.00, 3.81, 3.72, 3.92, 3.83, 4.12, 3.98, 3.70, and 3.97. The overall average $\bar{\bar{x}}$ is 3.90. Figure 2 shows this overall average $\bar{\bar{x}}$ as a solid line. The eleven sample averages are plotted as points which cluster about the overall average. The broken lines above and beneath the plotted points are the upper and lower control limits (UCL, LCL). Statistically speaking, these are three-sigma limits but we shall not elaborate on this point - See Appendix 1.1 . These control limits are not to be confused with tolerance limits which are discussed in Part c of this section. The fact that all of the points fall within the control limits is strong evidence that the sampling methods were carried out accurately and that the averages for the two letter size characteristics, height and length, did not change throughout the sampling period.

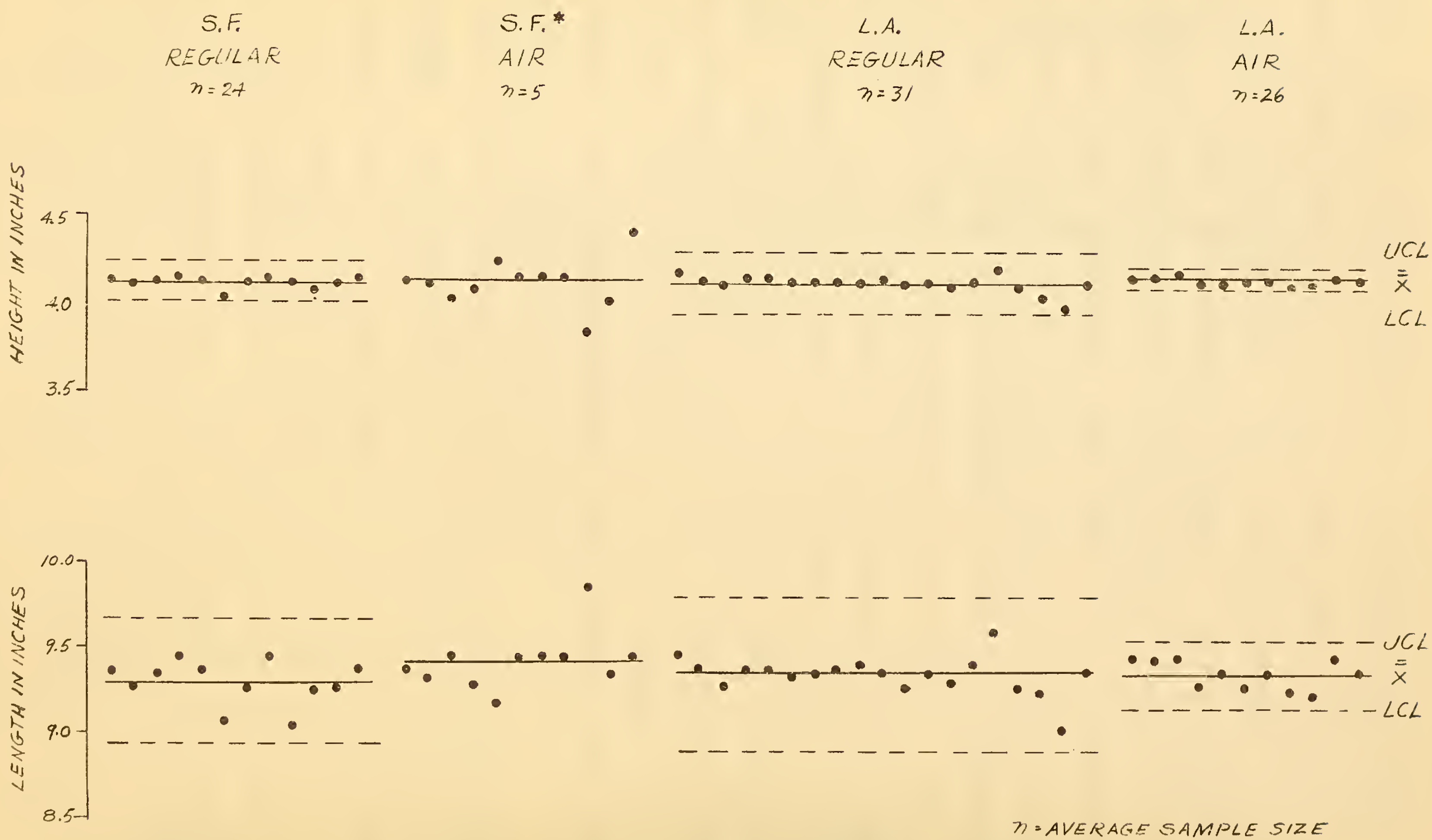
The control limits vary from one city and type of mail to another. The width of the band depends upon the size of the sample from which each sample average was calculated as well as the sample values themselves. The smaller the sample size, the wider the limits and vice versa. The average sample size n is listed for each part. The agreement between cities (Los Angeles and San Francisco) and types of letters (Regular and Air mail) is remarkably good. See Figures 2 and 3

Figure 2 Control charts for averages of Height and Length for Cancel Short mail data from S.F. and L.A.



*Note - Control limits are omitted to avoid erroneous comparison because average sample sizes are not comparable. Circled values represent only one letter. However, the grand averages ($\bar{\bar{X}}$) within each letter size characteristic (length or height) are still comparable.

Figure 3 Control charts for averages of Height and Length for Cancel Long mail data from S.F. and L.A.



* Note - Control limits are omitted to avoid erroneous comparison because average sample sizes are not comparable. However, the grand averages ($\bar{\bar{x}}$) within each letter size characteristic (length or height) are still comparable.

We also see that the average height of the sample of Short letters is slightly less than the average height of the sample of Long letters.

The control charts for Long letters are exceedingly uniform, and, in fact, a further statistical test showed that there is no significant difference in the average heights or the average lengths of Cancel mail. (A weighted analysis of variance was used throughout Part (a) to test differences between averages. See Appendix 1.2.)

The control charts for Short letters also exhibit fairly good uniformity; however, statistical tests show a significant difference in the average heights but no difference in the average lengths. It might be noted that circled points for Cancel Short Air mail at San Francisco by length are cases where the sample consisted of only one letter. This is the reason why these points are so far from their grand average and not because these points are averages of letters with abnormally large or small lengths. Since the average sample size was so small in comparison with the other average sample sizes, no control limits are shown.

Referring to the control charts for averages $\overline{x}$ for Cull mail in figures 4 and 5 , the average lengths of letters are not significantly different for the two cities, Los Angeles and San Francisco. Furthermore, there is no

Figure 4 Control charts for averages of Height for Cull mail data from S.F. and L.A.

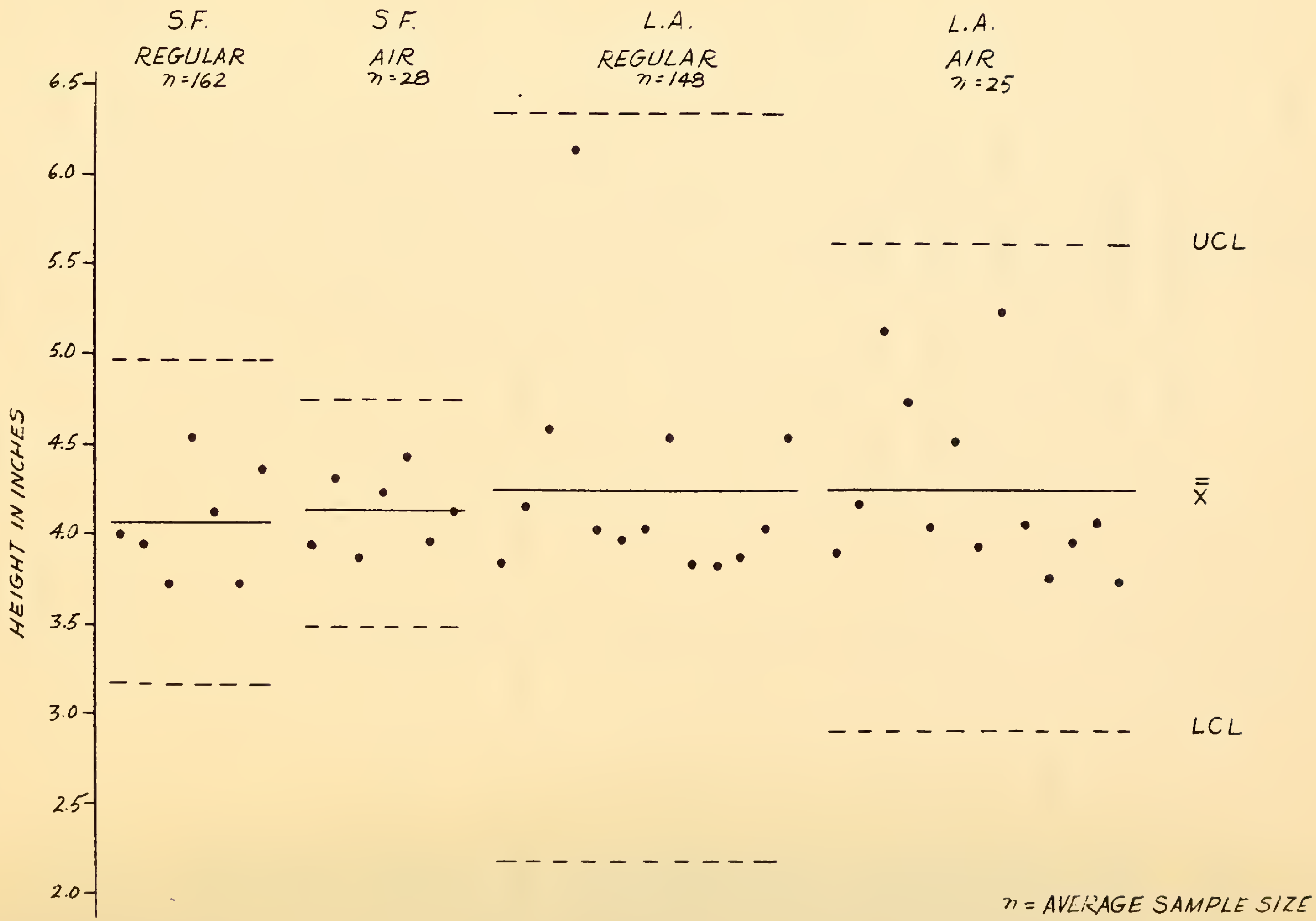
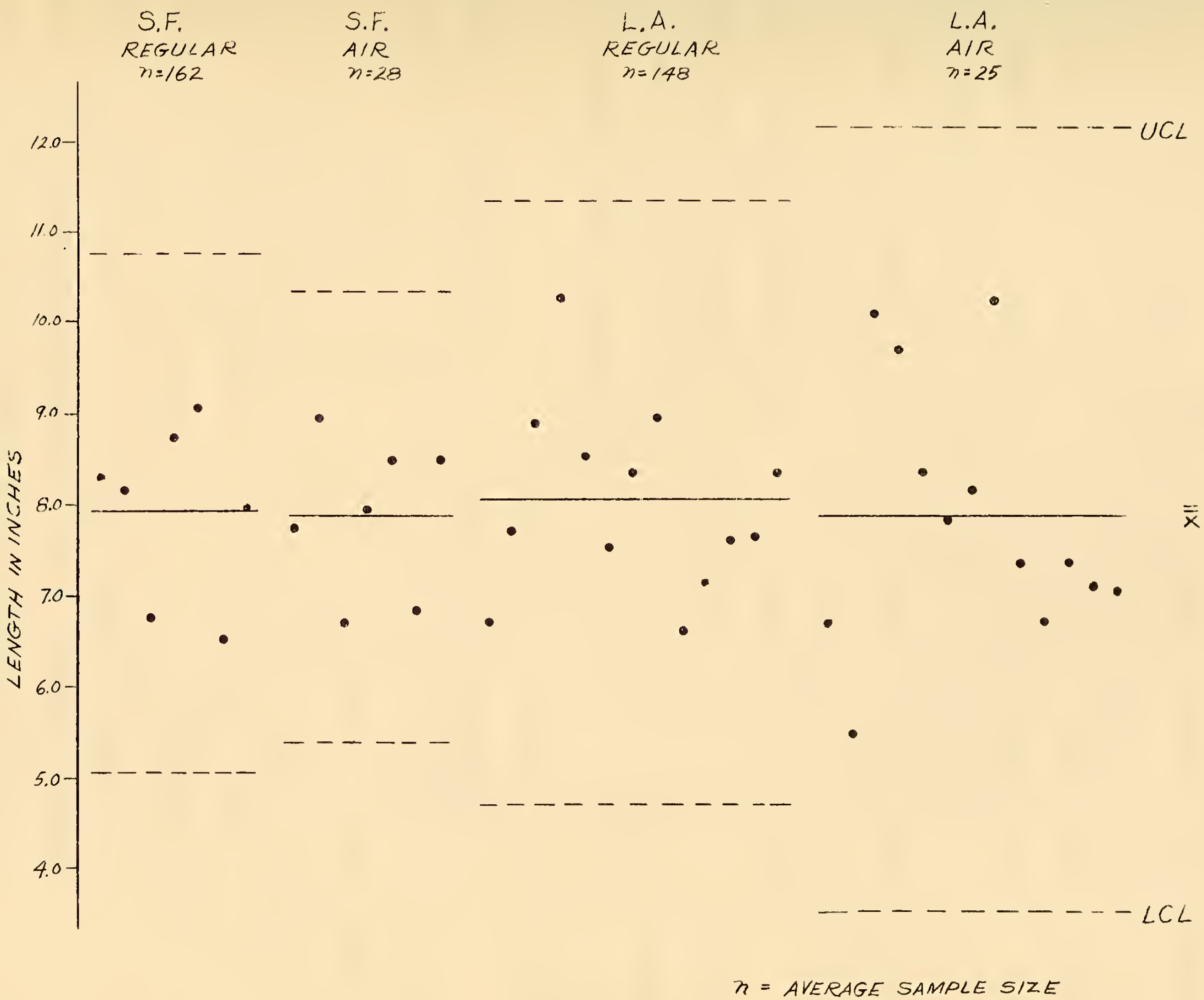


Figure 5 Control charts for averages of Length for Cull mail data from S.F. and L.A.

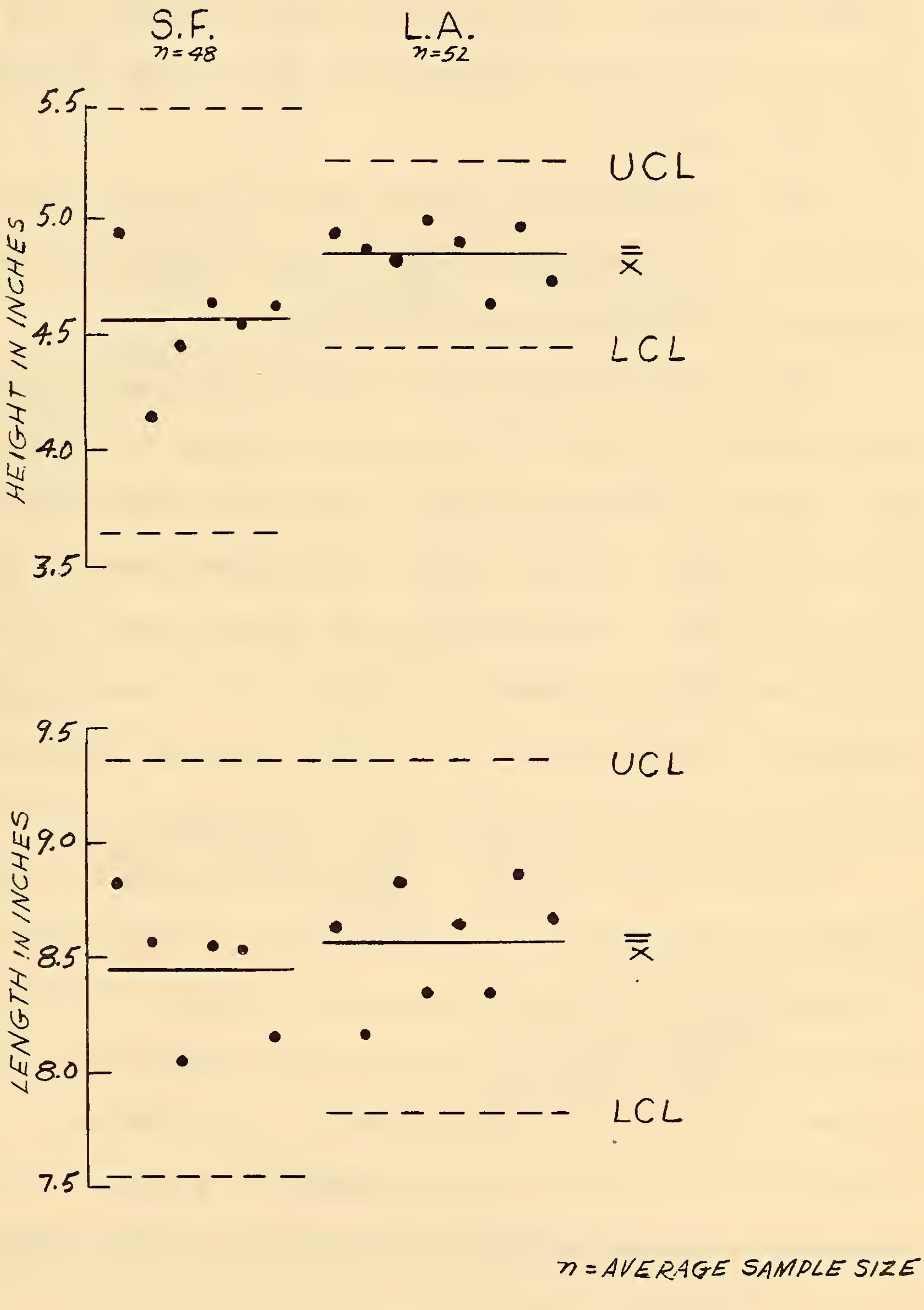


significant difference between the average lengths of Regular mail and Air mail. The variances of the heights for the four groups are not constant; therefore no test for differences between the average heights was made. At this point we would like to mention that the variability in Cull mail is much greater than that for Cancel mail. This is evidenced by the wide control limits on Cull mail as compared to narrower limits on Cancel mail. This further illustrates that the control limits are a function of the variability of the data as well as the sample size.

For Bulk mail, Figure 6 shows control charts for Bundles. There is no significant difference in the average lengths of Bundles between Los Angeles and San Francisco. But the two cities do differ significantly with respect to the average heights of Bundles.

b) <u>Comparison of cities</u>. It is interesting to note that the size characteristics of Cancel mail do not appear to differ from one region to another. We were able to show this by comparing San Francisco, Los Angeles, and Washington, D.C. two at a time. Statistical tests (Kolmogorov-Smirnov test was used throughout Part b, See Appendix 1.3.) verify that the cities do not differ significantly with respect to Cancel mail. However, there is one exception in Cancel Short Regular mail by length where it appears that San Francisco is much

Figure 6 Control charts for averages of Height and Length for Bulk mail by Bundles data from S.F. and L.A.



different from the others at one part of the distribution curve (see Figure 7). We believe this departure in the curves is explainable because a closer look at the original data indicated that an atypical sample, as compared to all other samples for Los Angeles, San Francisco, and Washington, D. C., was collected wherein over 40% of the letters fell in one size interval.

The comparison of cities just referred to is shown in Figures 7 through 11 which are cumulative percentage graphs of the sample distributions.

The data for all three cities have been plotted on the same graph in order to enable the reader to visually compare the sample distributions for the letter size characteristics. On each graph, the vertical scale gives percentages ranging from 0 to 100. Horizontally the scale gives the size characteristic measured in inches. The total number of letters in each sample (i.e., the size of the entire sample distribution) is recorded near each graph as N = Sample Size.

Figures 12, 13, 16 show the cumulative percentage graphs for Cull mail. For Cull mail the plotted sample distributions show good agreement between Los Angeles and San Francisco. In fact, statistical tests show that the two cities do not differ significantly with respect to length and height of Air mail, nor the height of Regular mail; however, the two cities do differ significantly with respect to the length of Regular mail.

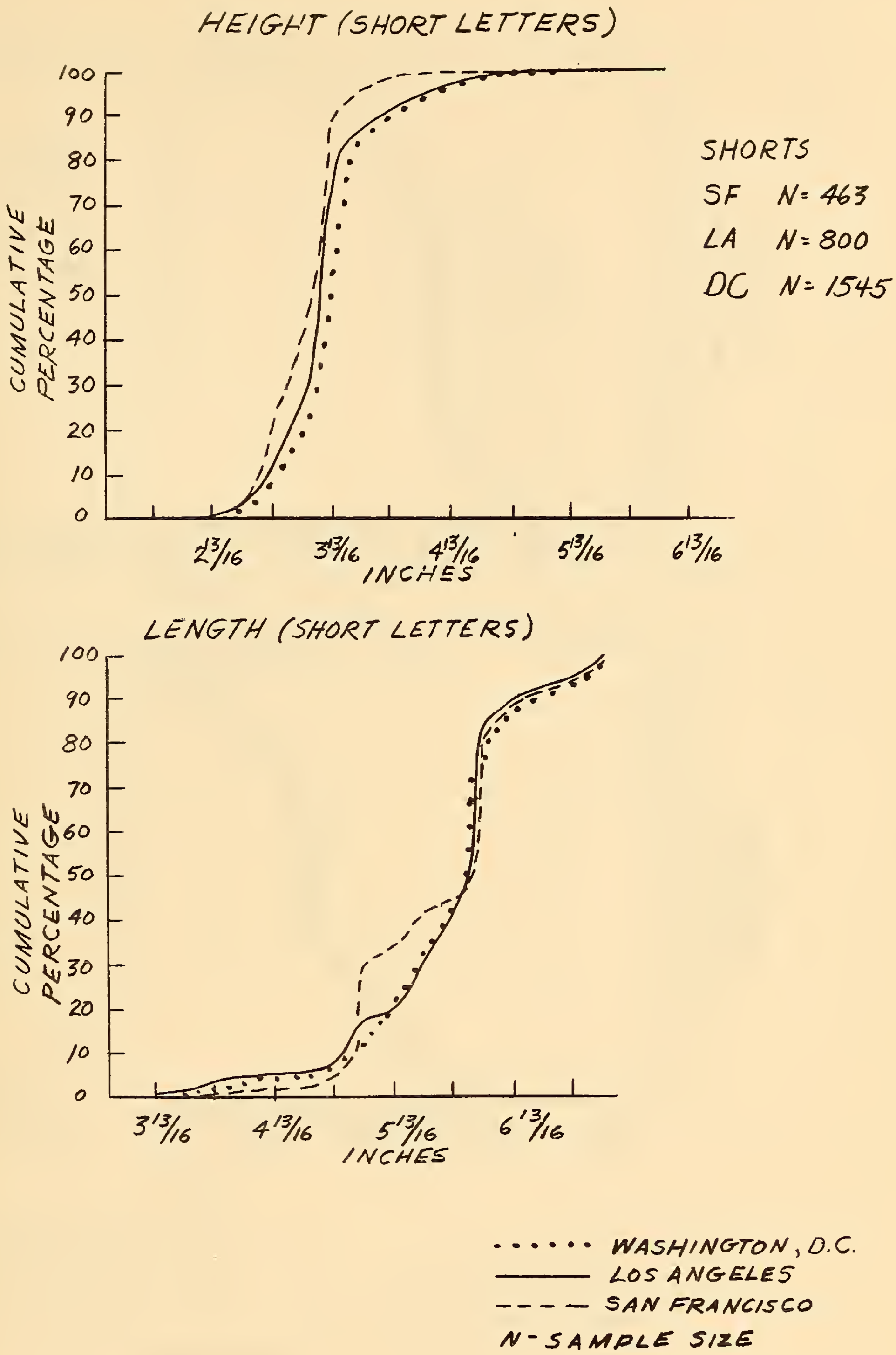


Figure 7

Cumulative percentage curves for Height and Length of Cancel Short Regular mail data of S.F., L.A., and D.C.

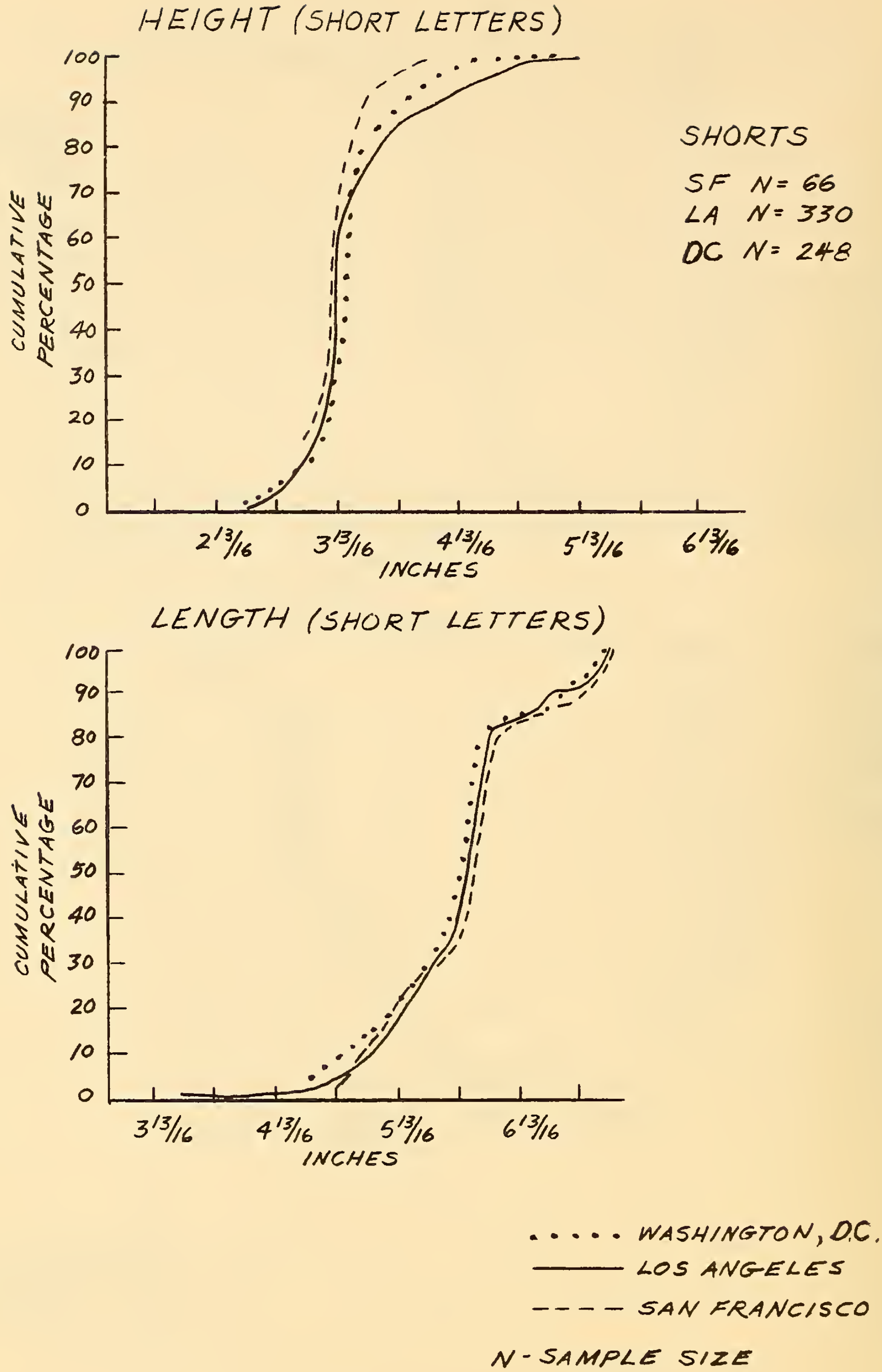


Figure 8

Cumulative percentage curves for Height and Length of Cancel Short Air mail data for S.F., L.A., and D.C.

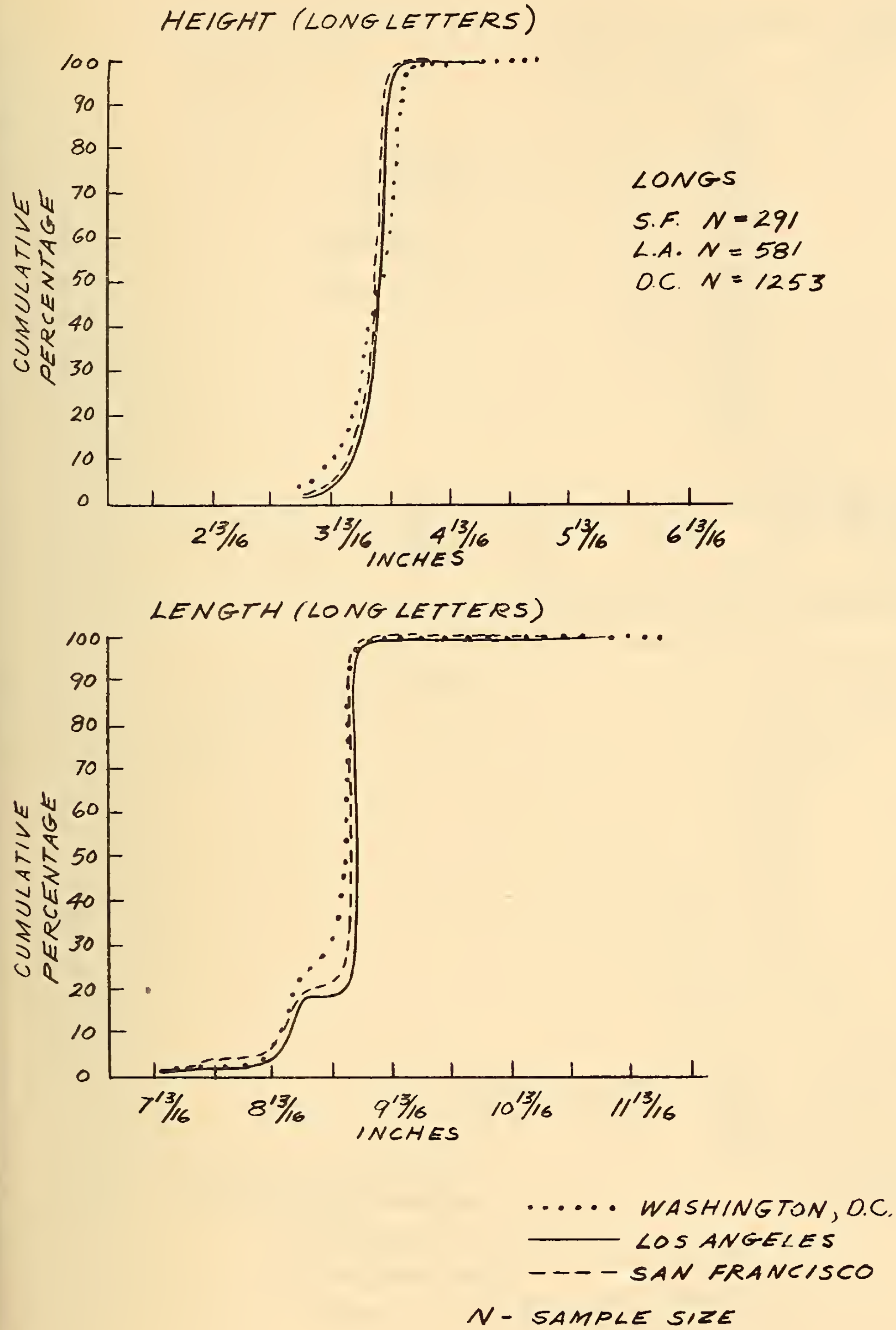


Figure 9

Cumulative percentage curves for Height and Length of Cancel Long Regular mail data for S.F., L.A., and D.C.

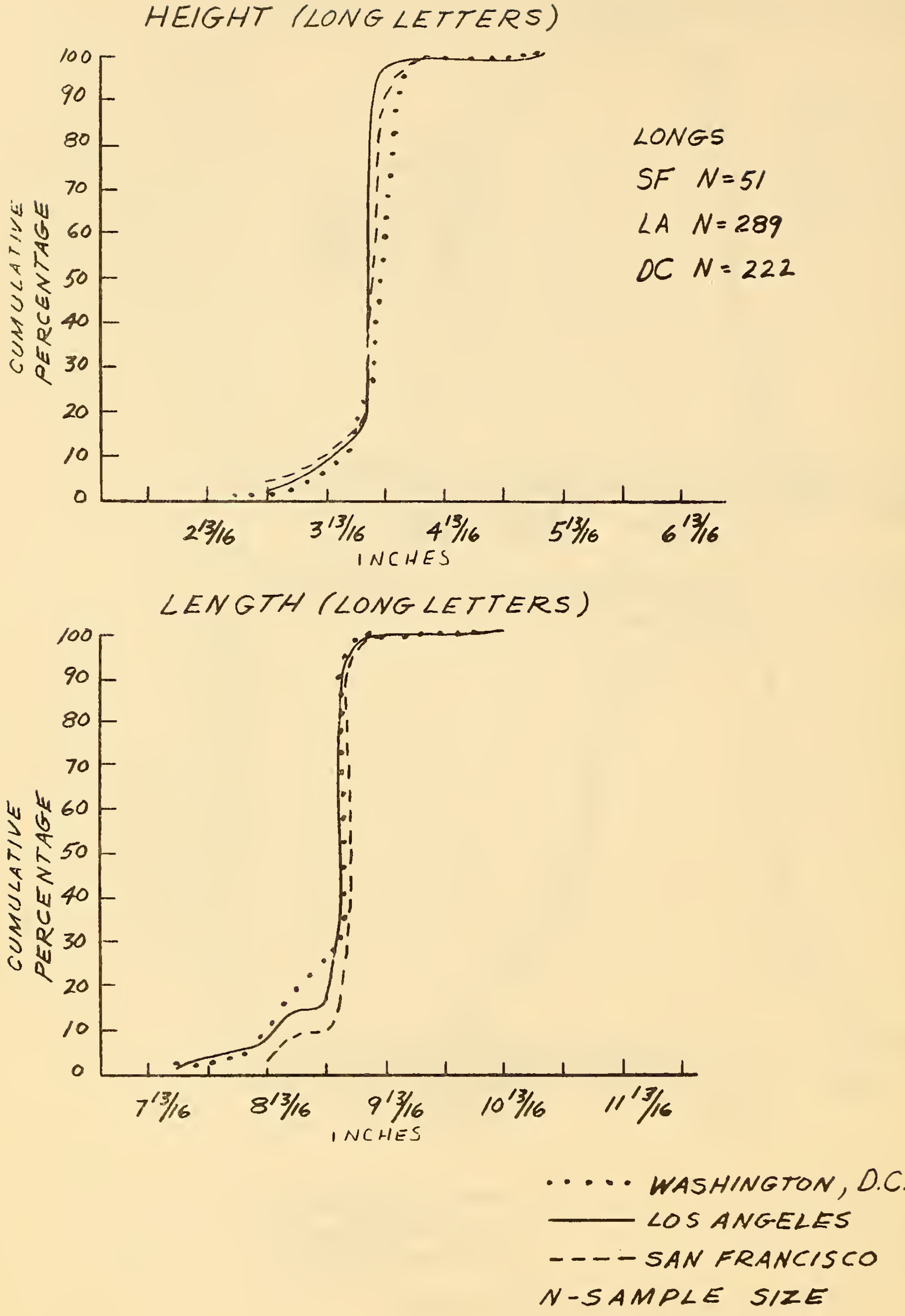


Figure 10

Cumulative percentage curves for Height and Length of Cancel Long Air mail data for S.F., L.A., and D.C.

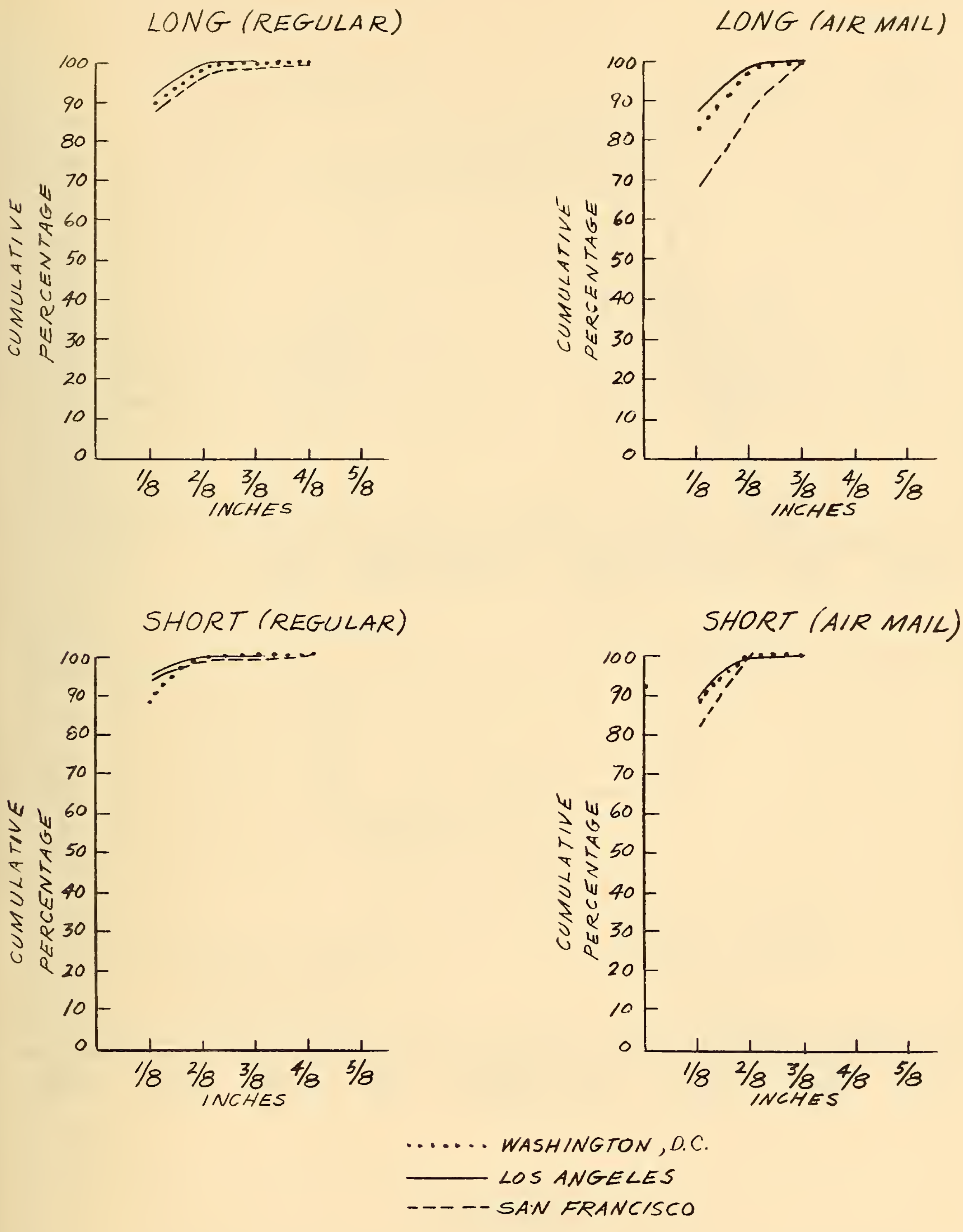
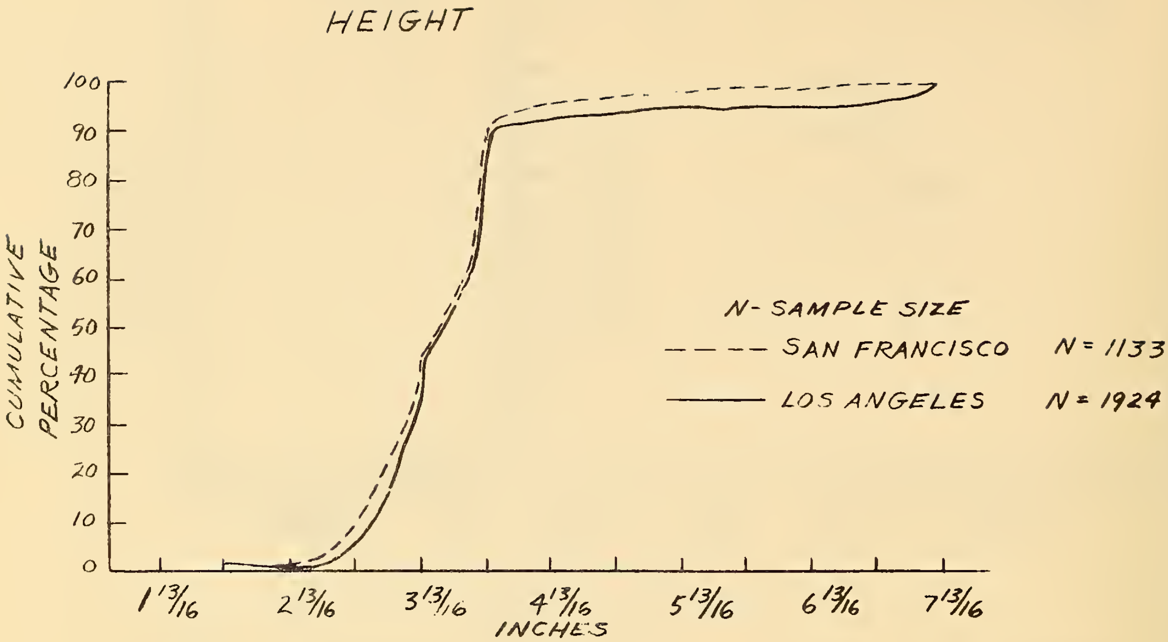


Figure 11

Cumulative percentage curves for Thickness of Cancel mail data for S.F., L.A., and D.C.



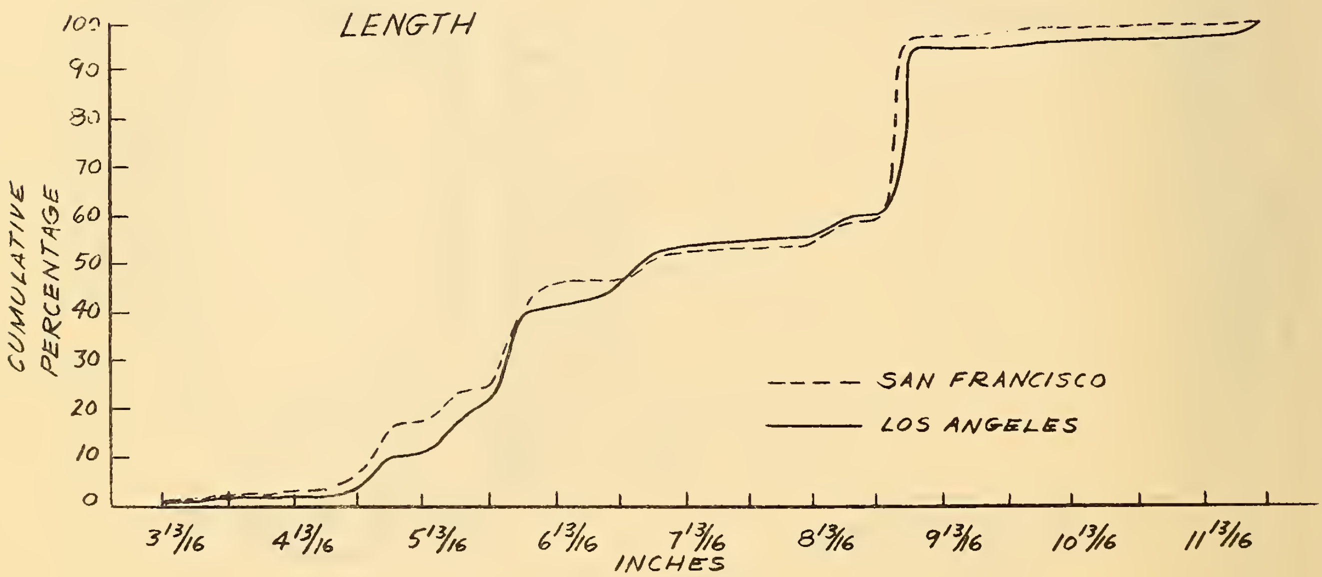


Figure 12

Cumulative percentage curves for Height and Length of Cull Regular mail data for S.F. and L.A.

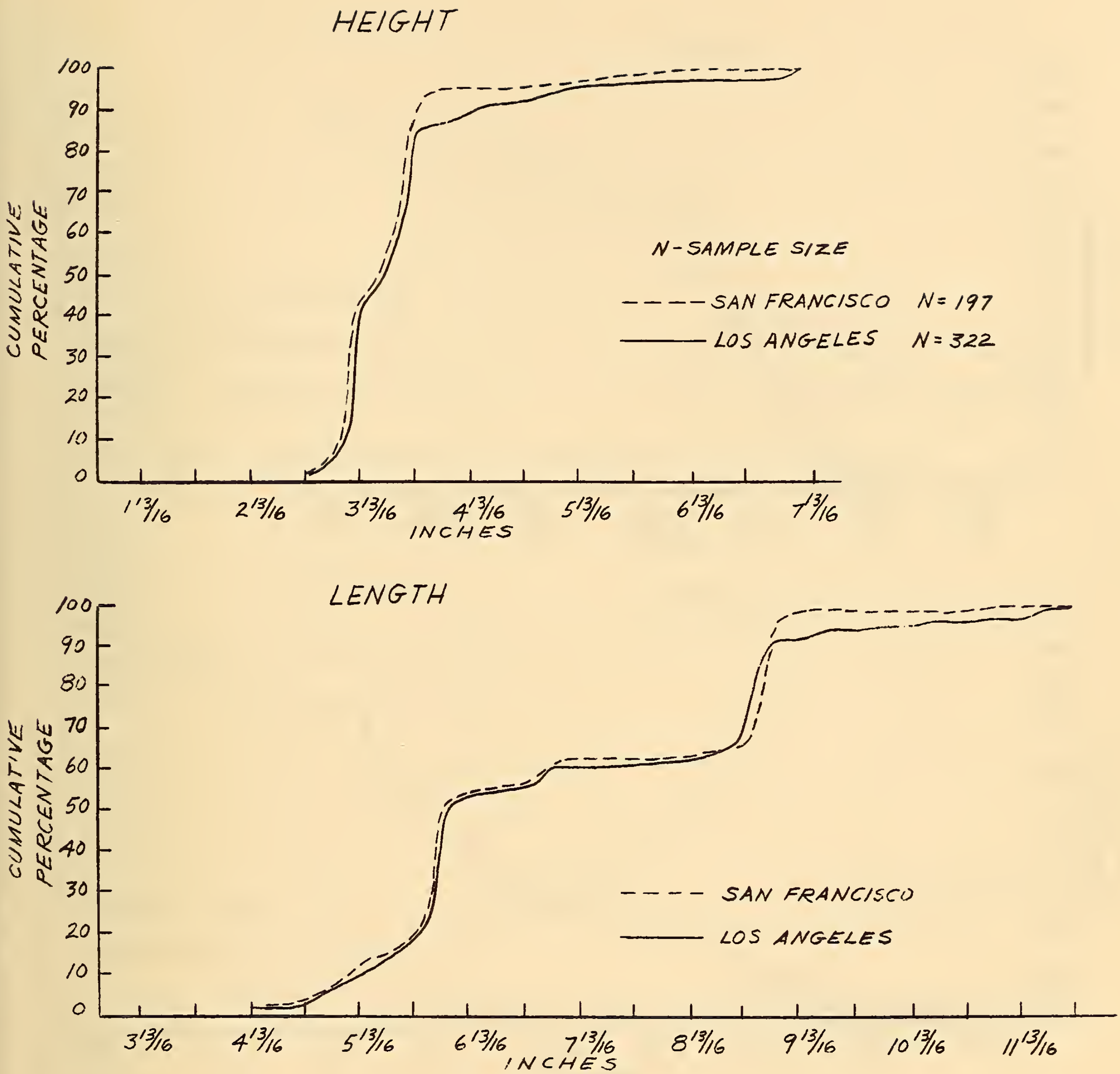


Figure 13

Cumulative percentage curves for Height and Length of Cull Air mail data for S.F. and L.A.

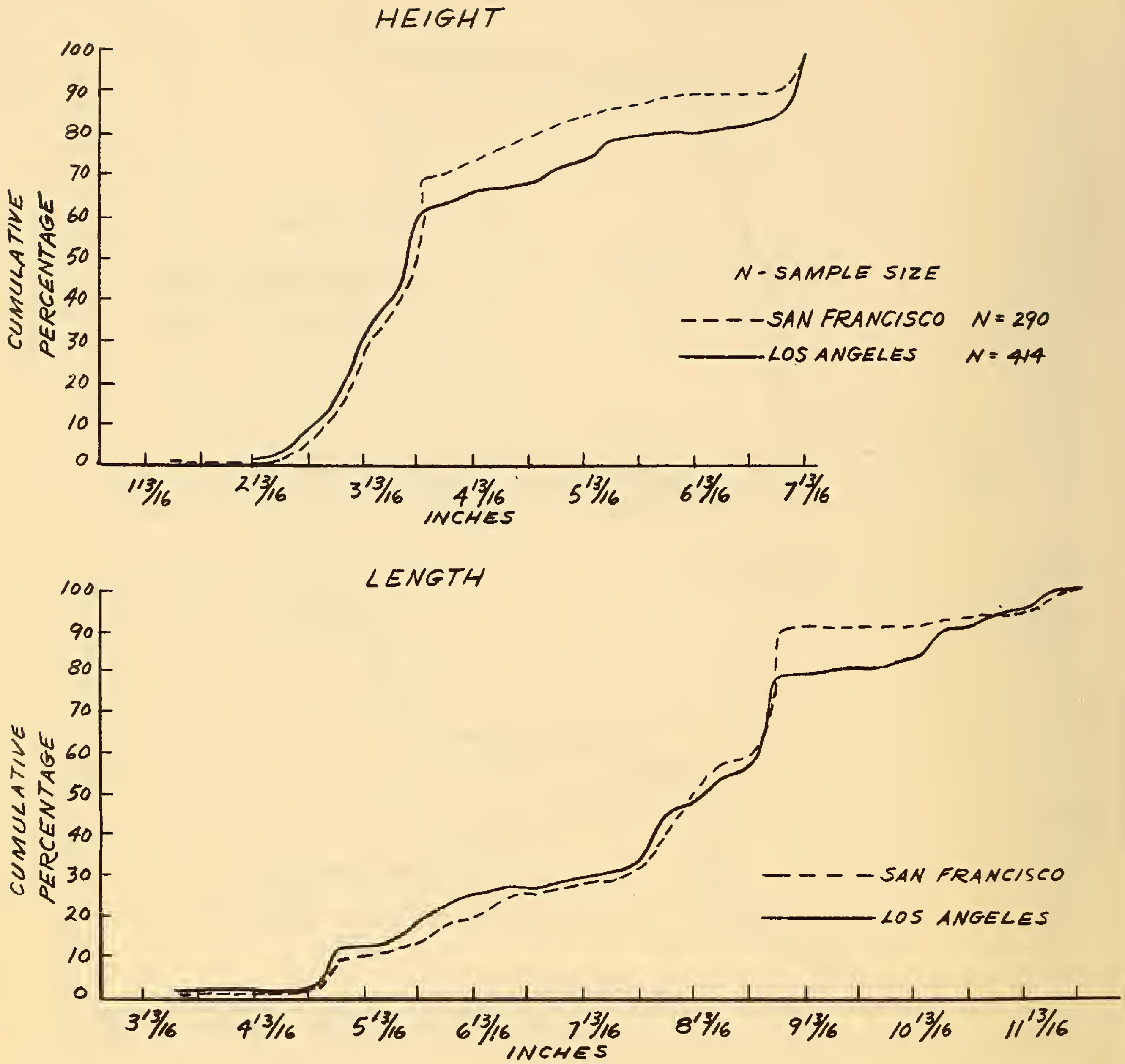
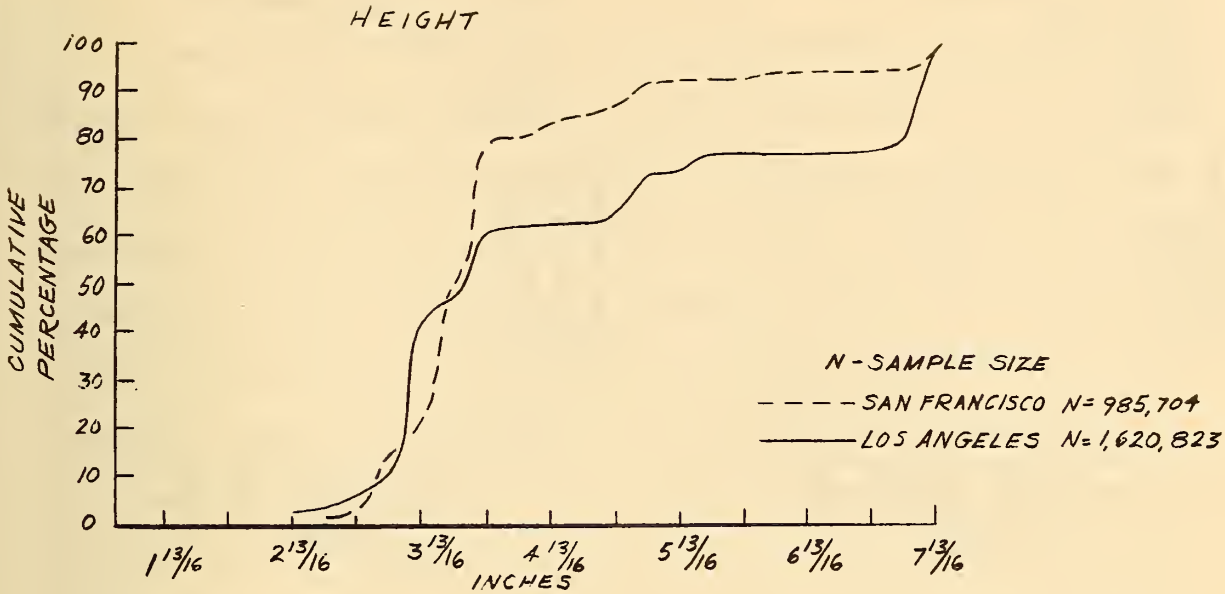


Figure 14

Cumulative percentage curves for Height and Length of Bulk mail by Bundles data for S.F. and L.A.



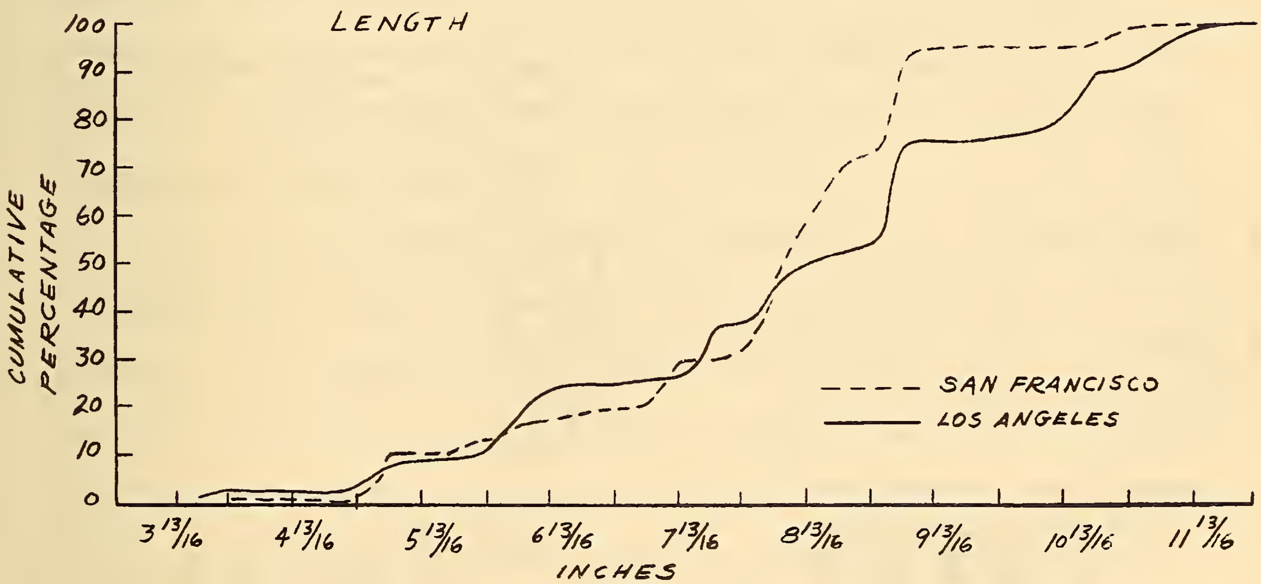


Figure 15

Cumulative percentage curves for Height and Length of Bulk mail by Letters data for S.F. and L.A.

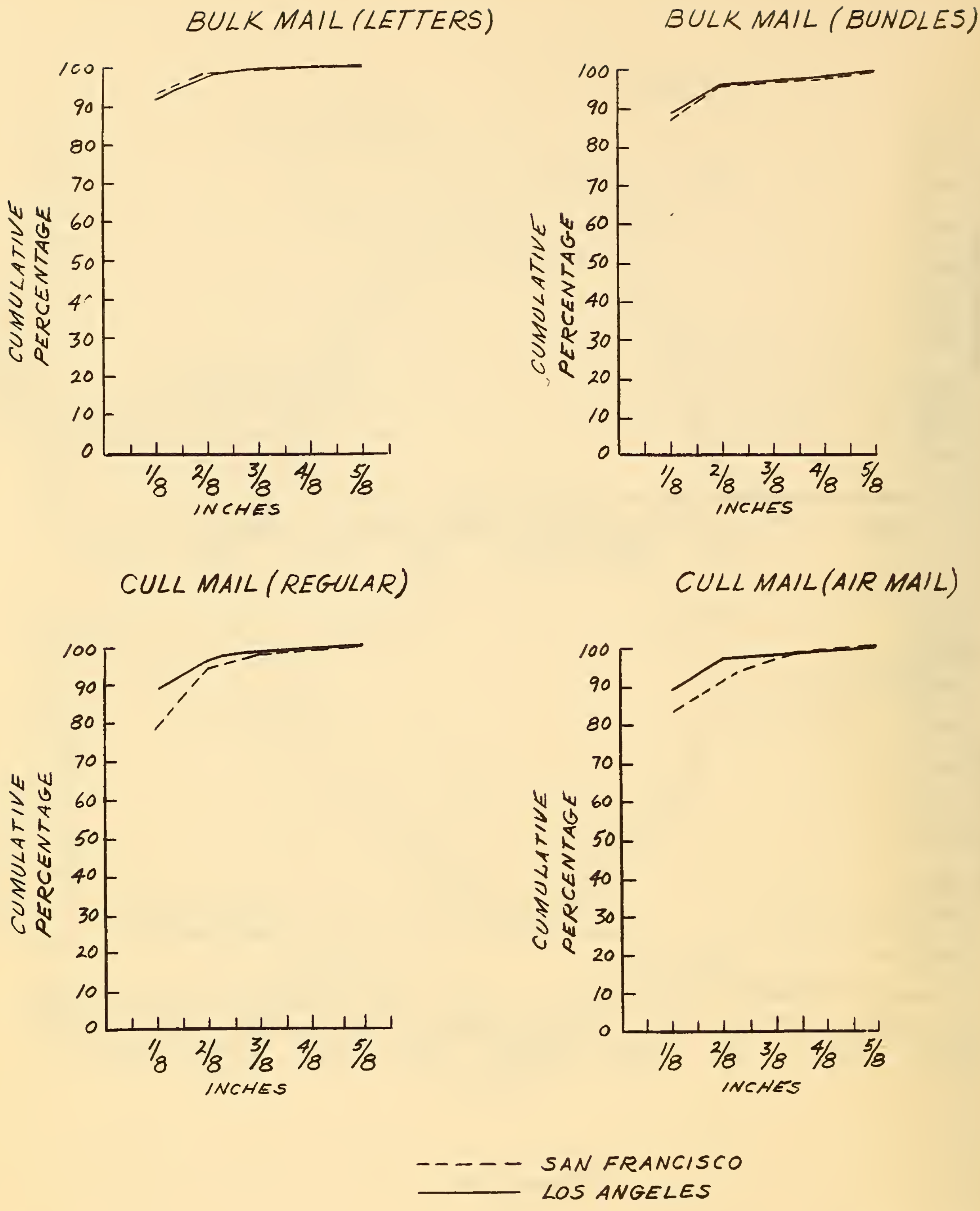


Figure 16

Cumulative percentage curves for Thickness of Bulk mail and Cull mail data for S.F. and L.A.

Due to the limitation of the device for measuring sizes, there were a large number of letters that were either smaller or larger than could be measured. (This was especially the case for Cull mail and Bulk mail.) These letters were lumped together in the "catch-all" classes of "less than" or "greater than." This is particularly true of the "greater than" category where in some cases as much as 10% of the mail sampled was too large for the measuring device. This amounts to loss of information when we really do not know what the distribution is like in the "larger than" category. We, therefore, recommend that in any future sampling studies the device for measuring sizes be enlarged to cope with the bigger sized envelopes.

Figures 14 through 16 show cumulative percentage graphs for Bulk mail both by Bundles and by Letters. From the graphs it is evident by the departure in the curves that the length and height characteristics of Bulk mail are apparently not the same in Los Angeles as in San Francisco. Statistical tests verify that this departure is, in fact, statistically significant.

c) Tolerance limits. One might next ask if we can be sure that at least a certain percentage of the mail, for each letter size characteristic, will lie within certain sizes.

The answer is yes; it is possible to predict with a prescribed confidence coefficient that at least a fixed percentage of the mail will lie within certain size limits. These predictions are called tolerance limits and they show the predicted limits within which at least a specified proportion of the mail is contained. There are two types of tolerance limits, two-sided limits and one-sided limits. If we are interested in two limits which contain at least a specified proportion of the mail, we use two-sided limits. If we are interested in only one limit, either above which or below which at least a specified proportion of the mail will lie, then we use one-sided limits. The confidence coefficient for Tables 23 to 31 and 41 to 43 was .95, which means that we shall be correct in expecting at least the prescribed percentage of the mail to be within the tolerance limits unless the sample from which we deduced this result was anomalous to an extent that would arise no more than one time in twenty. For detailed discussions of statistical tolerance limits see the references referred to in Appendix 2.1 .

The tolerance limits for the length of Cancel mail are one-sided. This is due to the breaking point between Short and Long letters. A Short letter, by definition, has a limiting length less than 7 9/16 inches and so we only are interested in the proportion of letters that are greater than a certain size.

Tables 23 through 31 show tolerance limits which are predicted sizes which contain at least 90%, 95%, and 99% of each type of mail. We can see that for Cancel mail (Tables 23 through 26) the three cities are fairly consistent in the size intervals that include various proportions of the mail. The tolerance limits point out the fact that the culling or separation procedure varies from one post office to another with regard to the definition of "oversize." For instance, it is apparent from the tolerance limits on Cancel mail that more letters are culled between the sizes 9 9/16 and 10 9/16 inches at Los Angeles than at San Francisco (see Tables 25, 26). In other words, the definitions of what constitutes the oversized mail that is pulled out before facing are not uniform.

Table 27 shows the 90%, 95%, and 99% tolerance limits on Metered mail based on data from San Francisco. This is the only Metered mail sample collected; therefore no comparisons between cities can be made.

It was not possible to place 90%, 95%, and 99% tolerance limits on Cull mail as has been done on Cancel mail because a sizable proportion of the sample distributions fell in the "greater than" class. That is, there was a considerable number of the envelopes that could not be measured because they were larger than at least one dimension of the measuring device and therefore these envelopes were lumped in the "greater than" class. In order to discuss and compare Cull mail, we

TABLE 23

Predicted lower and upper limits for 90%, 95%, and 99% of Cancel Short Regular mail based on data from S.F., and L.A., and D.C. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

	Lower Tolerance Limit		Upper Tolerance Limit	
Percent of mail covered	Height (in inches)	Length (in inches)	Height (in inches)	Length (in inches)
		San Francisco		
90%	3 2/16	5 5/16	4 1/16	(a)
95%	3 1/16	5 5/16	4 5/16	(a)
99%	3 1/16	4 5/16	4 13/16	(a)
		Los Angeles		
90%	3 1/16	5 5/16	4 12/16	(a)
95%	2 15/16	4 5/16	5 1/16	(a)
99%	2 5/16	3 13/16	6 5/16	(a)
		Washington, D. C.		
90%	3 2/16	5 2/16	4 9/16	(a)
95%	3 1/16	4 15/16	4 14/16	(a)
99%	3 1/16	4 4/16	5 1/16	(a)

(a) By definition, Short letters are less than 7 9/16 inches in length.

TABLE 24

Predicted lower and upper limits for 90%, 95%, and 99% of Cancel Short Air mail based on data from S.F., L.A., and D.C. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

Percent of mail covered	Lower Tolerance Limit Height (in inches)	Lower Tolerance Limit Length (in inches)	Upper Tolerance Limit Height (in inches)	Upper Tolerance Limit Length (in inches)
	San Francisco			
90%	3 9/16	5 6/16	4 5/16	(a)
95%	3 9/16	5 5/16	4 5/16	(a)
99%	3 9/16	5 5/16	4 5/16	(a)
	Los Angeles			
90%	3 5/16	5 7/16	5 1/16	(a)
95%	3 2/16	5 3/16	5 5/16	(a)
99%	3 1/16	4 1/16	5 9/16	(a)
	Washington, D. C.			
90%	3 2/16	5 2/16	4 12/16	(a)
95%	3 1/16	5 1/16	5 1/16	(a)
99%	3 1/16	5 1/16	5 1/16	(a)

(a) By definition, Short letters are less than 7 9/16 inches in length.

TABLE 25

Predicted lower and upper limits for 90%, 95%, and 99% of Cancel Long Regular mail based on data from S.F., L.A., and D.C. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

Percent of mail covered	Lower Tolerance Limit Height (in inches)	Lower Tolerance Limit Length (in inches)	Upper Tolerance Limit Height (in inches)	Upper Tolerance Limit Length (in inches)
		San Francisco		
90%	3 12/16	(a)	4 5/16	10 4/16
95%	3 9/16	(a)	4 5/16	10 5/16
99%	3 9/16	(a)	4 5/16	10 5/16
		Los Angeles		
90%	3 13/16	(a)	4 5/16	9 9/16
95%	3 10/16	(a)	4 5/16	9 9/16
99%	3 9/16	(a)	4 13/16	9 9/16
		Washington, D. C.		
90%	3 10/16	(a)	4 9/16	9 8/16
95%	3 9/16	(a)	4 9/16	9 9/16
99%	3 9/16	(a)	5 1/16	10 7/16

(a) By definition, Long letters are equal to or greater than 7 9/16 inches in length.

TABLE 26

Predicted lower and upper tolerance limits for 90%, 95%, and 99% of Cancel Long Air mail based on data from S.F., L.A., and D.C. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

Percent of mail covered	Lower Tolerance Limit		Upper Tolerance Limit	
	Height (in inches)	Length	Height (in inches)	Length
		San Francisco		
90%	3 5/16	(a)	4 5/16	10 9/16
95%	3 5/16	(a)	4 5/16	10 9/16
99%	3 5/16	(a)	4 5/16	10 9/16
		Los Angeles		
90%	3 13/16	(a)	4 5/16	9 9/16
95%	3 10/16	(a)	4 5/16	9 9/16
99%	3 9/16	(a)	5 5/16	9 9/16
		Washington, D. C.		
90%	3 9/16	(a)	5 1/16	9 9/16
95%	3 5/16	(a)	5 1/16	9 9/16
99%	3 1/16	(a)	5 1/16	10 1/16

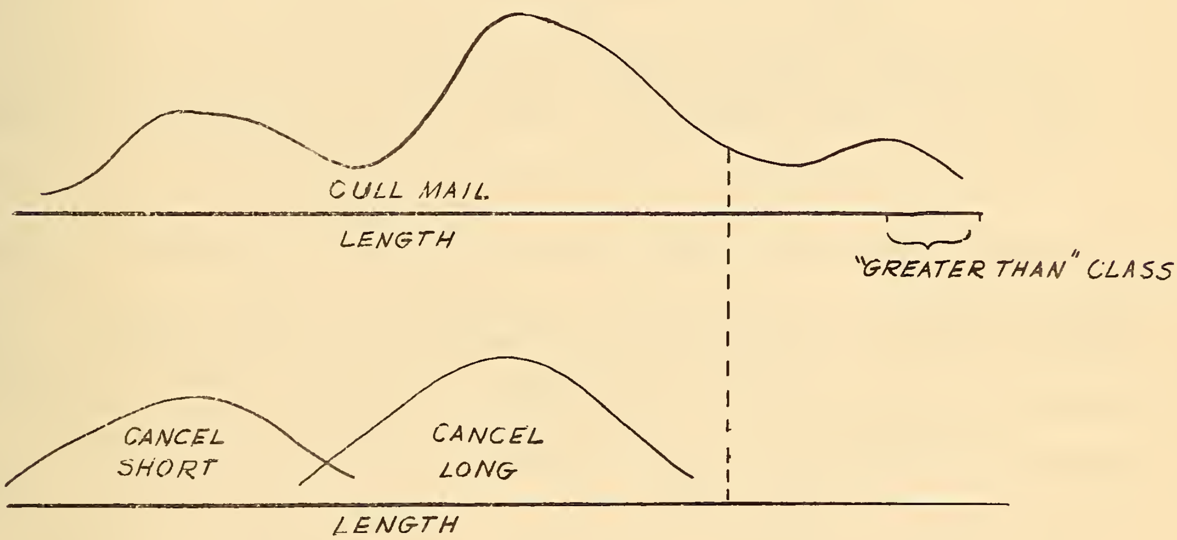
(a) By definition, Long letters are equal to or greater than 7 9/16 inches in length.

TABLE 27

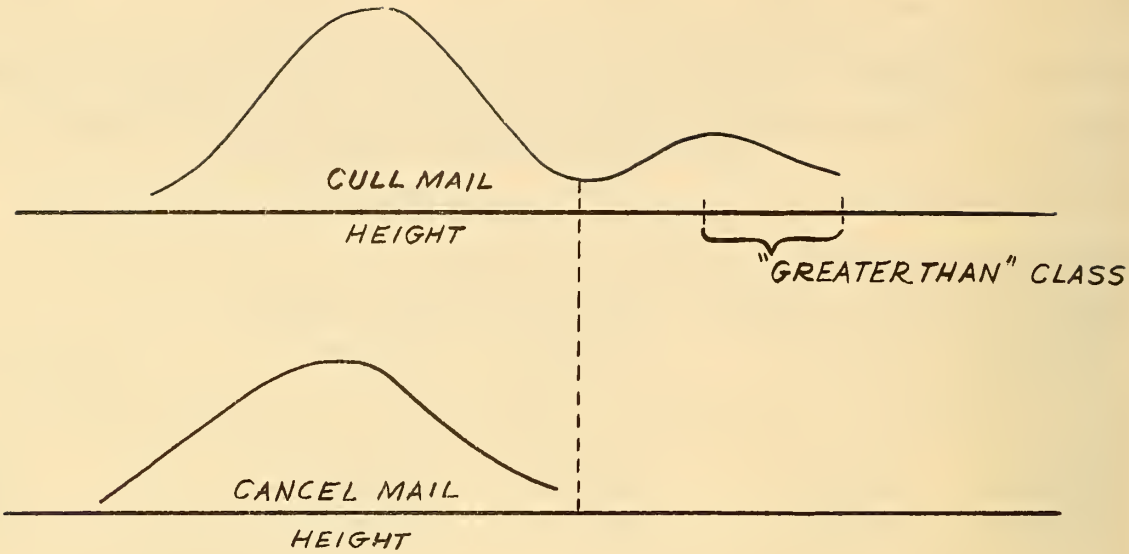
Predicted lower and upper limits for 90%, 95%, and 99% of Metered mail based on data from S.F. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

Percent of mail covered	Lower Tolerance Limit Height (in inches)	Lower Tolerance Limit Length (in inches)	Upper Tolerance Limit Height (in inches)	Upper Tolerance Limit Length (in inches)
90%	3 5/16	6 5/16	4 6/16	9 9/16
95%	3 4/16	5 7/16	4 9/16	10 5/16
99%	3 1/16	5 1/16	5 9/16	11 5/16

arbitrarily chose natural cut-off points which coincide with the Cancel mail sample distributions. For example the distributions of Cull, Cancel Short, Cancel Long mail by length have somewhat the patterns shown below (for the sake of comparison we have distorted the fact that the area under each of the distribution curves is equal to one):



A value (11 1/16") in the upper tail of the Cancel Long sample distribution was thus chosen as the cut-off point for the length of Cull mail. Similarly, the distributions of Cull mail and Cancel mail by height have somewhat the following patterns:



Again a value (5 9/16") in the upper tail of the Cancel sample distribution was chosen as the cut-off point for the height of Cull mail. These cut-off points are shown as dotted lines in Tables 14 and 15. Hence, letters greater than 5 9/16 inches in height, or greater than 11 1/16 inches in length are considered Oversize. Tables 28 and 29 show the sizes which include at least 90%, 95%, 99%, of all the Cull mail, but the reader should keep in mind that these are tolerance limits on truncated distributions as described above.

With few exceptions, there again seems to be fairly good agreement between Los Angeles and San Francisco with respect to the predicted sizes that will include at least certain proportions of the mail. Also, Table 32 shows the proportions (expressed as a percentage) with confidence limits, of the mail that we can expect to fall in the Oversize category. Los Angeles appears to have a larger proportion of Oversize mail than San Francisco.

Tables 30 and 31 give the tolerance limits that have been placed on Bulk mail. Again, three estimates have been given which include at least 90%, 95%, and 99% of all Bulk mail. Furthermore, here as in Cull mail there is a "greater than" class. Table 33 shows the "greater than" proportions and limits associated with these proportions.

Wherever permissible, as judged by the statistical tests cited in the above discussion, the data have been combined. In table 41 we present 95% tolerance limits for

TABLE 28

Predicted lower and upper limits for 90%, 95%, and 99% of Cull*Regular mail based on data from S.F. and L.A. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

Percent of mail covered	Lower Tolerance Limit Height (in inches)	Lower Tolerance Limit Length (in inches)	Upper Tolerance Limit Height (in inches)	Upper Tolerance Limit Length (in inches)
		San Francisco		
90%	3 2/16	5 3/16	4 5/16	9 9/16
95%	2 13/16	4 15/16	4 10/16	9 9/16
99%	2 13/16	3 13/16	5 5/16	11 1/16
		Los Angeles		
90%	3 4/16	5 5/16	4 5/16	9 12/16
95%	3 2/16	5 1/16	4 11/16	9 13/16
99%	2 12/16	4 3/16	5 1/16	10 9/16

*These limits have been determined by using the sample distributions truncated as described on page 73.

TABLE 29

Predicted lower and upper limits for 90%, 95%, and 99% of Cull*Air mail based on data from S.F. and L.A. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

Percent of mail covered	Lower Tolerance Limit		Upper Tolerance Limit	
	Height (in inches)	Length (in inches)	Height (in inches)	Length (in inches)
		San Francisco		
90%	3 8/16	5 6/16	4 5/16	9 9/16
95%	3 5/16	4 15/16	4 13/16	9 9/16
99%	3 5/16	4 13/16	5 1/16	9 9/16
		Los Angeles		
90%	3 8/16	5 6/16	4 4/16	9 13/16
95%	3 6/16	5 3/16	5 1/16	10 5/16
99%	3 5/16	5 1/16	5 5/16	10 13/16

*These limits have been determined by using the sample distributions truncated as described on page 73.

TABLE 30

Predicted lower and upper limits for 90%, 95%, and 99% of Bulk mail by Bundles based on data from S.F. and L.A. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

Percent of mail covered	Lower Tolerance Limit Height (in inches)	Lower Tolerance Limit Length (in inches)	Upper Tolerance Limit Height (in inches)	Upper Tolerance Limit Length (in inches)
		San Francisco		
90%	3 6/16	5 6/16	(b)	11 5/16
95%	3 3/16	5 5/16	(b)	(b)
99%	3 1/16	4 5/16	(b)	(b)
		Los Angeles		
90%	3 4/16	5 6/16	(b)	11 14/16
95%	3 1/16	5 5/16	(b)	11 16/16
99%	2 13/16	4 1/16	(b)	(b)

(b) No upper limits could be calculated because of the limitations of the measuring device.

TABLE 31

Predicted lower and upper limits for 90%, 95%, and 99% of Bulk mail by Letters based on data from S.F. and L.A. Table gives 90%, 95%, and 99% tolerance limits with confidence coefficient .95.

	Lower Tolerance Limit		Upper Tolerance Limit	
Percent of mail covered	Height (in inches)	Length (in inches)	Height (in inches)	Length (in inches)
		San Francisco		
90%	3 8/16	5 7/16	(b)	10 9/16
95%	3 6/16	5 6/16	(b)	11 4/16
99%	3 3/16	5 5/16	(b)	(b)
		Los Angeles		
90%	3 9/16	5 7/16	(b)	11 9/16
95%	3 5/16	5 5/16	(b)	11 14/16
99%	2 13/16	4 1/16	(b)	(b)

(b) No upper limits could be calculated because of the limitations of the measuring device.

Table 32 Percentages*with specified dimensions and the 99% confidence limits of Cull Regular and Cull Air mail

	Regular		Air Mail	
	San Francisco	Los Angeles	San Francisco	Los Angeles
Percent > 5 9/16 inches in height	3.1	6.3	4.1	6.2
99% Confidence limits	2%, 4%	4%, 8%	1%, 9%	3%, 11%
Percent > 11 1/16 inches in length	1.9	4.3	3.0	4.7
99% Confidence limits	1%, 3%	3%, 5%	1%, 7%	3%, 9%
Percent > 5 9/16 inches in height and > 11 1/16 inches in length	1.7	4.2	2.5	4.3
99% Confidence limits	1%, 3%	3%, 5%	1%, 7%	3%, 9%

*These are estimates of the percentages of mail cut-off in the truncation process described on page 73.

TABLE 33

Percentages*with specified dimensions and the 99% confidence limits of Bulk mail by Bundles and Bulk mail by Letters

	Bundles		Letters	
	San Francisco	Los Angeles	San Francisco	Los Angeles
Percent > 7 9/16 inches in height	10.3	16.9	5.6	22.1
99% Confidence limits	7%, 16%	13%,23%	3%, 11%	17%,27%
Percent > 12 1/16 inches in length	1.4	0.7	0.6	0.7
99% Confidence limits	0%, 3%	0%, 2%	0%, 2%	0%, 2%

*These are estimates of the percentages of mail whose measurements are greater than the limitations of the measuring device.

Cancel mail based on the combined San Francisco, Los Angeles and Washington, D. C. data. Table 42 gives 95% tolerance limits for Cull mail for the combined data of San Francisco and Los Angeles. Note that this latter table also presents tolerance limits based on the Regular and Air mail recombined as they were originally collected. The Oversized Cull mail is not represented here. Table 43 presents 95% tolerance limits based on all the Cancel Regular mail samples collected at San Francisco and Los Angeles. This includes both Long and Short letters. These can be combined because the samples of Long and Short letters were taken approximately in proportion to their relative volume as estimated by the method of Section 6

Figures 17 through 22 are frequency histograms of the combined data discussed in Tables 41 through 43 . The original data for these figures appear in Tables 34 through 40 . The histograms show the relative frequencies of the data for each corresponding size interval. In addition Figures 17 and 18 also portray the 95% tolerance limits previously tabulated. No tolerance limits are given on thickness; however, it is interesting to note the following interval estimates (i.e., .99 confidence limits) for the proportion of a given type mail less than or equal to 2/8 inches in thickness:

TABLE 34

Frequency (f) and relative frequency (r.f.) by designated Length of Cancel Short and Cancel Long mail at S.F., L.A., and D.C. combined

Interval in Inches	Short Letters				Long Letters			
	Regular		Air Mail		Regular		Air Mail	
	f	r.f.	f	r.f.	f	r.f.	f	r.f.
3 9/16 to 4 1/16	13	.01	1	.00				
4 1/16 to 4 9/16	50	.02						
4 9/16 to 5 1/16	63	.02	13	.02				
5 1/16 to 5 9/16	674	.24	90	.14				
5 9/16 to 6 1/16	394	.14	111	.17				
6 1/16 to 6 9/16	1130	.40	317	.49				
6 9/16 to 7 1/16	287	.10	44	.07				
7 1/16 to 7 9/16	197	.07	68	.11				
7 9/16 to 8 1/16					13	.01	5	.01
8 1/16 to 8 9/16					37	.02	14	.02
8 9/16 to 9 1/16					405	.19	66	.12
9 1/16 to 9 9/16					1638	.77	467	.83
9 9/16 to 10 1/16					4	.00	4	.01
10 1/16 to 10 9/16					21	.01	5	.01
10 9/16 to 11 1/16					4	.00	1	.00
11 1/16 to 11 9/16					2	.00		
11 9/16 to 12 1/16					1	.00		
Total Sample Size	2808	1.00	644	1.00	2125	1.00	562	1.00

TABLE 35

Frequency (f) and relative frequency (r.f.) by designated Height of Cancel Short and Cancel Long mail at S.F., L.A., and D.C. combined

Interval in Inches	Short Letters				Long Letters			
	Regular		Air Mail		Regular		Air Mail	
	f	r.f.	f	r.f.	f	r.f.	f	r.f.
2 1/16 to 2 9/16	2	.00	3	.01				
2 9/16 to 3 1/16	54	.02	56	.09			1	.00
3 1/16 to 3 9/16	947	.34	202	.31	16	.01	7	.01
3 9/16 to 4 1/16	1481	.53	288	.45	460	.22	74	.13
4 1/16 to 4 9/16	192	.07	56	.09	1640	.77	478	.85
4 9/16 to 5 1/16	109	.04	25	.04	7	.00		
5 1/16 to 5 9/16	16	.01	12	.02	2	.00	2	.00
5 9/16 to 6 1/16	3	.00	2	.00				
6 1/16 to 6 9/16	4	.00						
6 9/16 to 7 1/16								
7 1/16 to 7 9/16								
Total Sample Size	2808	1.01	644	1.01	2125	1.00	562	.99

TABLE 36

Frequency (f) and relative frequency (r.f.) by designated Thickness of Cancel Short and Cancel Long mail at S.F., L.A., and D.C. combined

Interval in Inches	Short Letters				Long Letters			
	Regular		Air Mail		Regular		Air Mail	
	f	r.f.	f	r.f.	f	r.f.	f	r.f.
0 to 1/8	2603	.93	574	.89	1840	.87	470	.84
1/8 to 2/8	186	.07	67	.10	235	.11	75	.13
2/8 to 3/8	17	.01	3	.01	44	.02	17	.03
3/8 to 4/8	2	.00			6	.00		
4/8 to 5/8								
Total Sample Size	2808	1.01	644	1.00	2125	1.00	562	1.00

TABLE 37

Frequency (f) and relative frequency (r.f.) by designated Length of Cull mail at S.F. and L.A. combined

Interval in Inches	Regular		Air Mail		Regular + Air	
	f	r.f.	f.	r.f.	f	r.f.
< 3 13/16	6	.00			6	.00
3 9/16 to 4 1/16	1	.00			1	.00
4 1/16 to 4 9/16	18	.01			18	.01
4 9/16 to 5 1/16	45	.01	4	.01	49	.01
5 1/16 to 5 9/16	296	.10	30	.06	326	.09
5 9/16 to 6 1/16	195	.06	41	.08	236	.07
6 1/16 to 6 9/16	686	.22	189	.36	875	.24
6 9/16 to 7 1/16	105	.03	19	.04	124	.03
7 1/16 to 7 9/16	232	.08	36	.07	268	.07
7 9/16 to 8 1/16	30	.01	1	.00	31	.01
8 1/16 to 8 9/16	19	.01	6	.01	25	.01
8 9/16 to 9 1/16	159	.05	6	.01	165	.05
9 1/16 to 9 9/16	1113	.36	154	.30	1267	.35
9 9/16 to 10 1/16	8	.00	6	.01	14	.00
10 1/16 to 10 9/16	31	.01	4	.01	35	.01
10 9/16 to 11 1/16	8	.00	2	.00	10	.00
11 1/16 to 11 9/16	3	.00	2	.00	5	.00
11 9/16 to 12 1/16	52	.02	11	.02	63	.02
> 12 1/16	50	.02	8	.02	58	.02
Total Sample Size	3057	.99	519	1.00	3576	.99

TABLE 38

Frequency (f) and relative frequency (r.f.) by designated Height of Cull mail at S.F. and L.A. combined

Interval in Inches	Regular f	Regular r.f.	Air Mail f	Air Mail r.f.	Regular + Air f	Regular + Air r.f.
2 1/16 to 2 9/16	1	.00			1	.00
2 9/16 to 3 1/16	48	.02			48	.01
3 1/16 to 3 9/16	505	.17	29	.06	534	.15
3 9/16 to 4 1/16	1058	.35	247	.48	1305	.36
4 1/16 to 4 9/16	1212	.40	190	.37	1402	.39
4 9/16 to 5 1/16	63	.02	20	.04	83	.02
5 1/16 to 5 9/16	14	.00	5	.01	19	.01
5 9/16 to 6 1/16	9	.00	6	.01	15	.00
6 1/16 to 6 9/16	10	.00	1	.00	11	.00
6 9/16 to 7 1/16	2	.00			2	.00
7 1/16 to 7 9/16	19	.01	2	.00	21	.01
> 7 9/16	116	.04	19	.04	135	.04
Total Sample Size	3057	1.01	519	1.01	3576	.99

TABLE 39

Frequency (f) and relative frequency (r.f.) by designated Thickness of Cull mail at S.F. and L.A. combined

Interval in Inches	Regular f	Regular r.f.	Air Mail f	Air Mail r.f.	Regular + Air f	Regular + Air r.f.
0 to 1/8	2613	.85	449	.87	3062	.86
1/8 to 2/8	304	.10	41	.08	345	.10
2/8 to 3/8	77	.03	14	.03	91	.03
3/8 to 4/8	28	.01	6	.01	34	.01
4/8 to 5/8	13	.00	3	.01	16	.00
> 5/8	22	.01	6	.01	28	.01
Total Sample Size	3057	1.00	519	1.01	3576	1.01

TABLE 40

Frequency (f) and relative frequency (r.f.) by designated Thickness, Height, and Length of Cancel Regular mail (includes both Long and Short letters) at S.F. and L.A. combined

Interval in Inches	Thickness		Height		Length	
	f	r.f.	f	r.f.	f	r.f.
0 to 1/8	1978	.93				
1/8 to 2/8	136	.06				
2/8 to 3/8	18	.01				
3/8 to 4/8	3	.00				
4/8 to 5/8						
> 5/8						
1 9/16 to 2 1/16						
2 1/16 to 2 9/16			2	.00		
2 9/16 to 3 1/16			29	.01		
3 1/16 to 3 9/16			390	.18		
3 9/16 to 4 1/16			885	.41	11	.01
4 1/16 to 4 9/16			765	.36	22	.01
4 9/16 to 5 1/16			51	.02	27	.01
5 1/16 to 5 9/16			6	.00	223	.10
5 9/16 to 6 1/16			3	.00	143	.07
6 1/16 to 6 9/16			4	.00	627	.29
6 9/16 to 7 1/16					118	.06
7 1/16 to 7 9/16					92	.04
> 7 9/16						
7 9/16 to 8 1/16					7	.00
8 1/16 to 8 9/16					15	.01
8 9/16 to 9 1/16					148	.07
9 1/16 to 9 9/16					691	.32
9 9/16 to 10 1/16					1	.00
10 1/16 to 10 9/16					8	.00
10 9/16 to 11 1/16						
11 1/16 to 11 9/16					2	.00
11 9/16 to 12 1/16						
> 12 1/16						
Total Sample Size	2135	1.00	2135	.99	2135	.99

TABLE 41

Predicted lower and upper limits for 95% of Cancel mail based on data from S.F., L.A., and D.C. combined. Table gives 95% tolerance limits with confidence coefficient .95.

	Lower Tolerance Limit		Upper Tolerance Limit	
	Regular	Air Mail	Regular	Air Mail
Short Letters (in inches)				
Height	3 1/16	2 10/16	4 14/16	5 2/16
Length	5 1/16	5 2/16	(a)	(a)
Long Letters (in inches)				
Height	3 10/16	3 9/16	4 9/16	4 9/16
Length	(a)	(a)	9 9/16	9 9/16

(a) By definition, Short letters are less than 7 9/16 inches in length and Long letters are equal to or greater than 7 9/16 inches.

TABLE 42

Predicted lower and upper limits for 95% of Cull* Regular, Cull Air, and Cull Regular and Air mail based on data from S.F. and L.A. combined. Table gives 95% tolerance limits with confidence coefficient .95.

Type of Mail	Lower Tolerance Limit		Upper Tolerance Limit	
	Height (in inches)	Length	Height (in inches)	Length
Regular	3 1/16	5 0/16	4 11/16	9 9/16
Air Mail	3 9/16	5 3/16	4 14/16	9 13/16
Regular and Air Mail	3 1/16	5 1/16	4 12/16	9 9/16

TABLE 43

Predicted lower and upper limits for 95% of Cancel mail (Long and Short letters combined) based on data from S.F. and L.A. combined. Table gives 95% tolerance limits with confidence coefficient .95.

Type of Mail	Lower Tolerance Limit		Upper Tolerance Limit	
	Height (in inches)	Length	Height (in inches)	Length
Regular	3 1/16	4 12/16	4 12/16	9 9/16

* These limits have been determined by using the combined sample distributions truncated as described on page 73.

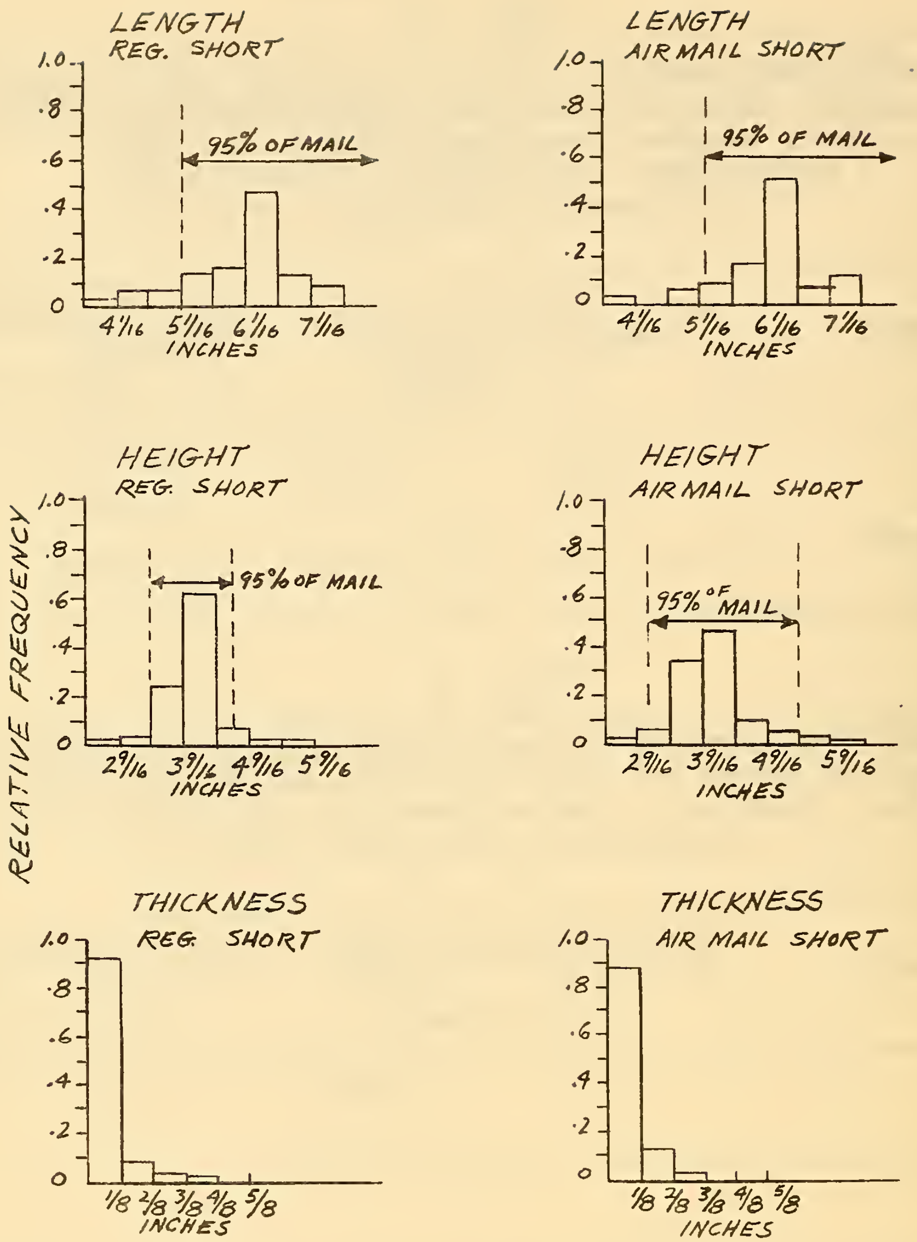


Figure 17

Relative frequency histograms for Length, Height, and Thickness of Cancel Short mail for combined data of S.F., L.A., and D. C.

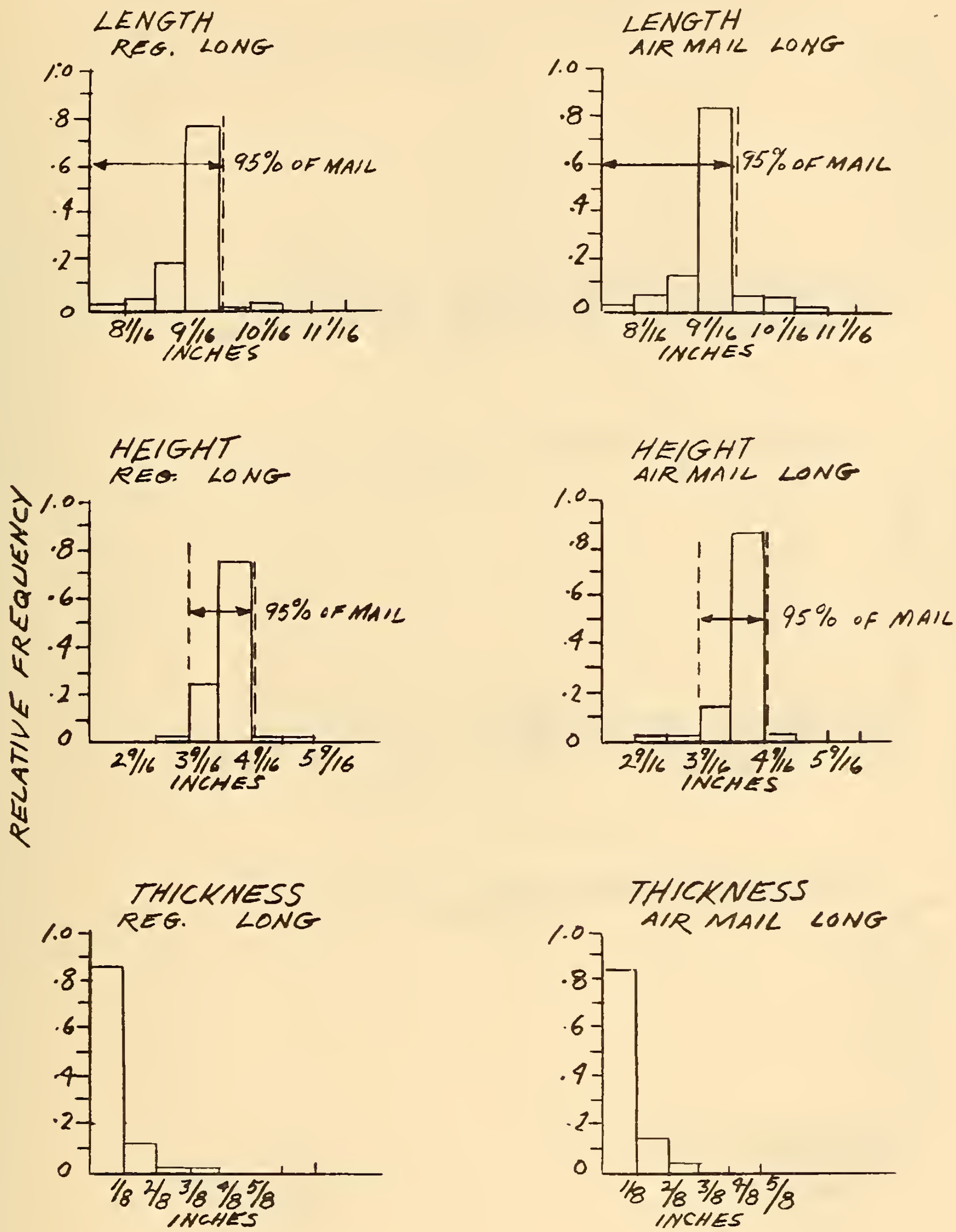


Figure 18

Relative frequency histograms for Length, Height, and Thickness of Cancel Long mail for combined data of S.F., L.A., and D.C.

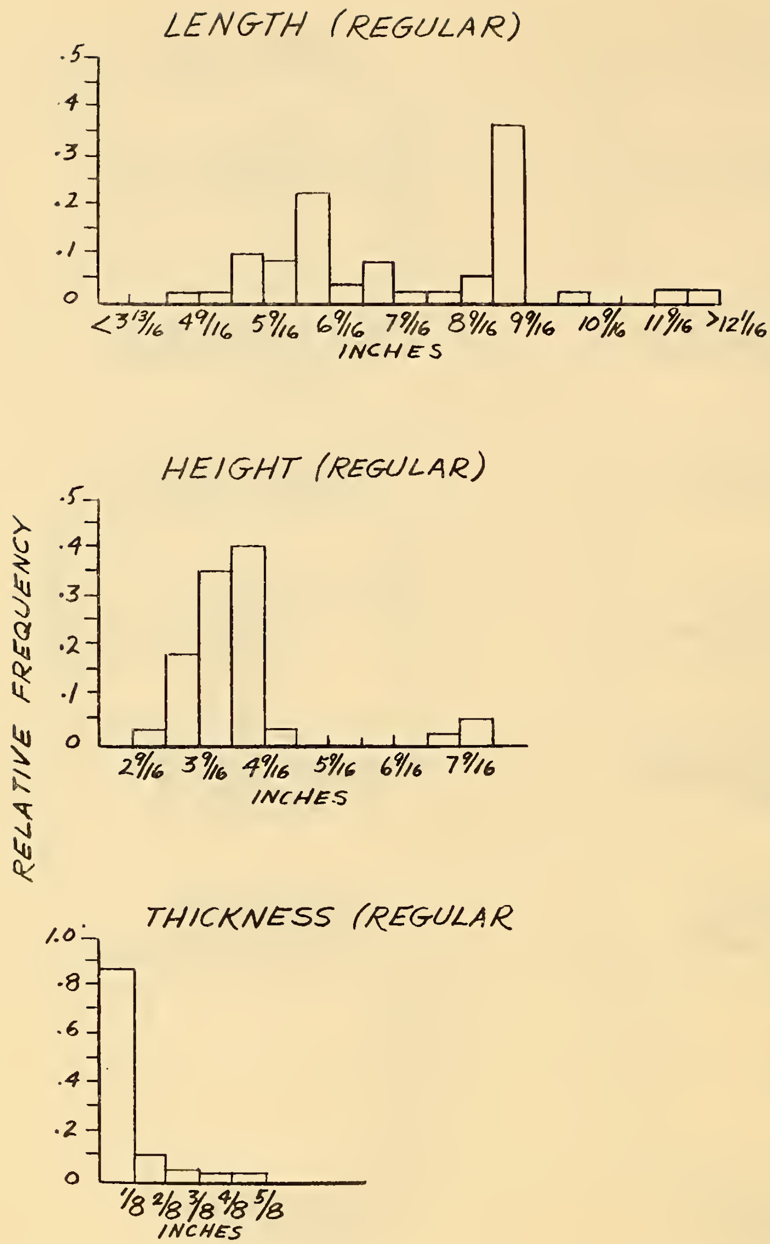


Figure 19

Relative frequency histograms for Length, Height, and Thickness of Cull Regular mail for combined data of S.F. and L.A.

Figure 21

Relative frequency histograms for Length, Height, and Thickness of Cull Regular plus Air Mail for combined data of S.F. and L.A.

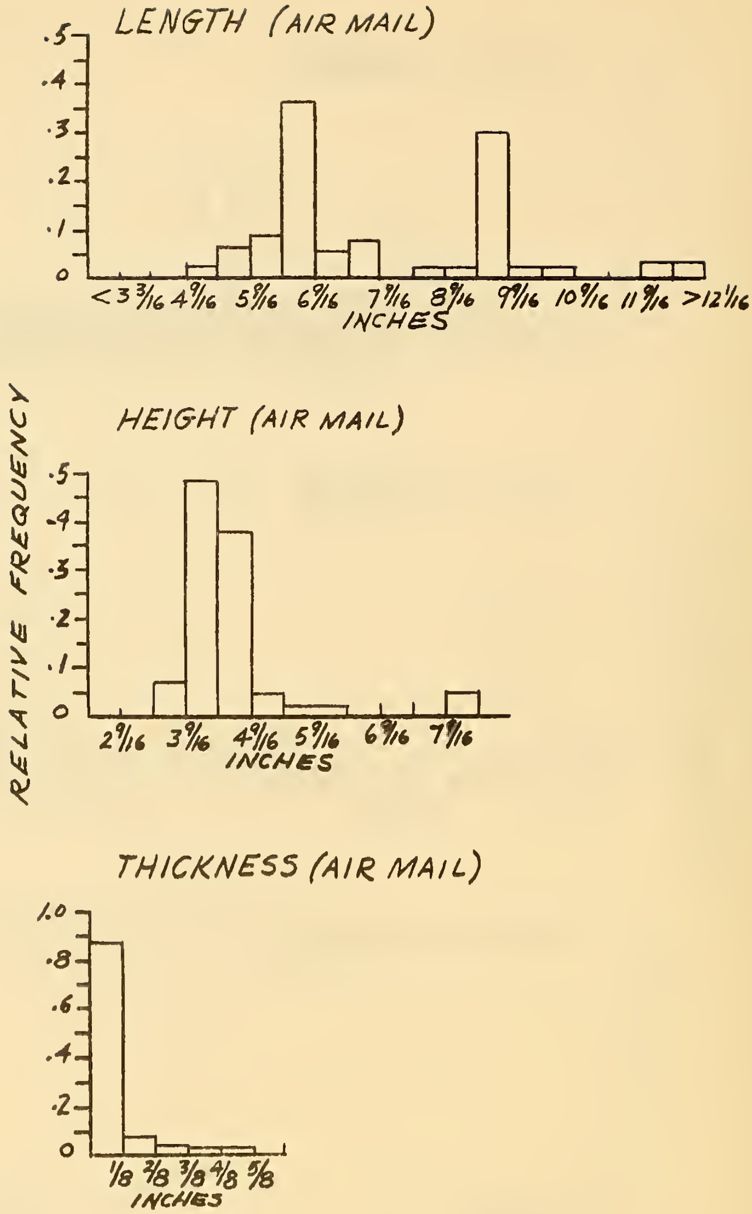


Figure 20

Relative frequency histograms for Length, Height, and Thickness of Cull Air mail for combined data of S.F. and L.A.

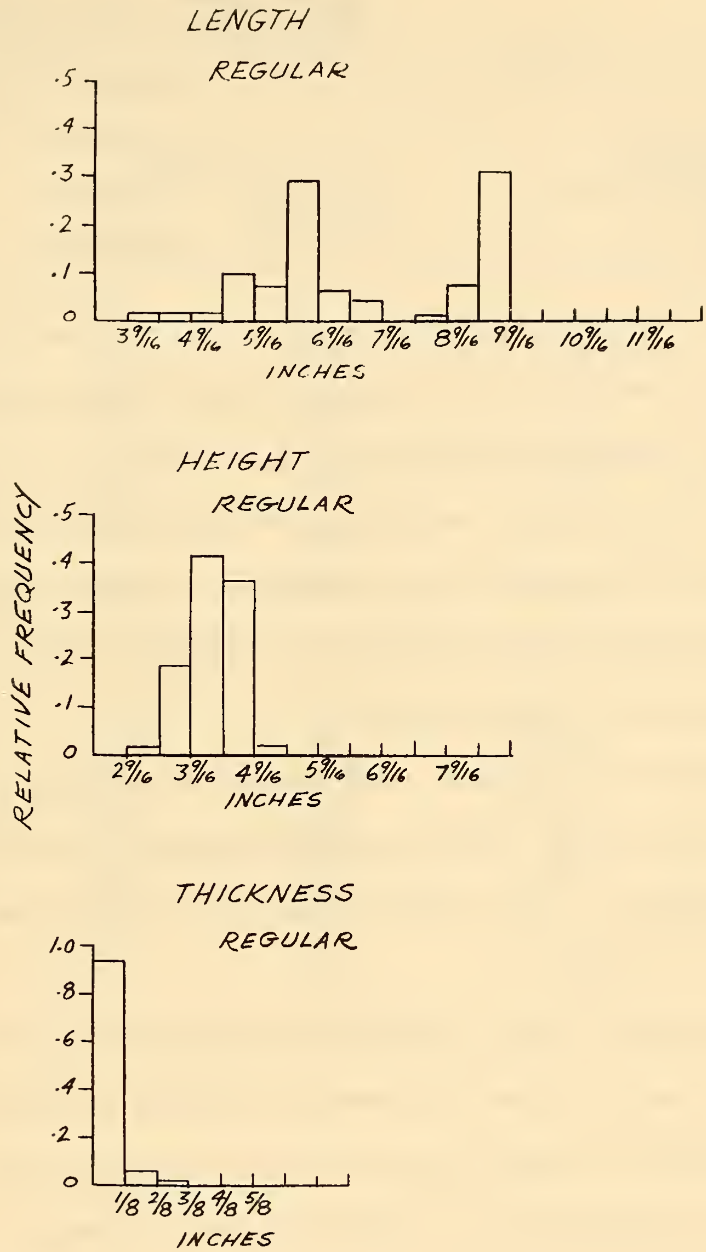


Figure 22

Relative frequency histograms for Length, Height, and Thickness of Cancel mail for combined data of S.F. and L.A.

	Proportion less than or equal to 2/8 inches in thickness
Short Regular mail	.983 to 1.000
Short Air mail	.985 to 1.000
Long Regular mail	.967 to .987
Long Air mail	.960 to .980

3.2.2 Color Characteristic. At the request of the Post Office Department a fourth letter size characteristic, color, was recorded during the San Francisco and Los Angeles studies. This record was made at the same time the other three characteristics were measured. Color indication was made according to the following: White, Yellow, Red, Blue, Gray, Brown, and Multi-color.

Tables 44 through 46 show the sample distributions of color in Cancel, Cull, and Metered mail for San Francisco and Los Angeles. The tables also list relative frequencies according to color.

Statistical tests (Kolmogorov-Smirnov test used here) show that there is no difference between Los Angeles and San Francisco in the colors of Cull Regular mail. There also is no difference in Cull Air mail between the cities. There is no difference between cities in Cancel Regular mail but there is a significant difference in Cancel Air mail. Sufficient investigation has not been made to explain why such a difference should exist. This difference may be due to the

TABLE 44

Frequency and relative frequency by designated Color of Cancel Regular and Cancel Air mail at S.F. and L.A.

Color	Regular		Air Mail	
	Frequency	Relative Frequency	Frequency	Relative Frequency
SAN FRANCISCO:				
White	613	.88	64	.66
Yellow	32	.05	1	.01
Red	5	.01	1	.01
Blue	17	.02	7	.07
Gray	13	.02	23	.24
Brown	17	.02	1	.01
Multi-color	2	.00		
TOTAL	699	1.00	97	1.00
LOS ANGELES:				
White	1131	.87	494	.82
Yellow	54	.04	10	.02
Red	5	.00	4	.01
Blue	53	.04	67	.11
Gray	40	.03	20	.03
Brown	15	.01	5	.01
Multi-color	3	.00	4	.01
TOTAL	1301	.99	604	1.01

TABLE 45

Frequency and relative frequency by designated Color of Cull Regular and Cull Air mail at S.F. and L.A.

Color	Regular		Air Mail	
	Frequency	Relative Frequency	Frequency	Relative Frequency
SAN FRANCISCO:				
White	795	.84	138	.72
Yellow	50	.05	4	.02
Red	4	.00	2	.01
Blue	17	.02	15	.08
Gray	18	.02	27	.14
Brown	68	.07	7	.04
Multi-color				
TOTAL	952	1.00	193	1.01
LOS ANGELES:				
White	1503	.84	218	.71
Yellow	84	.05	8	.03
Red	11	.01	2	.01
Blue	42	.02	51	.17
Gray	59	.03	9	.03
Brown	94	.05	17	.06
Multi-color				
TOTAL	1793	1.00	305	1.01

TABLE 46

Frequency and relative frequency by designated Color of Metered mail at S.F.

Color	Regular	
	Frequency	Relative Frequency
SAN FRANCISCO:		
White	548	.91
Yellow	5	.01
Red		
Blue	3	.00
Gray	28	.05
Brown	16	.03
Multi-color	1	.00
TOTAL	601	1.00

small sample size taken in San Francisco, or to the fact that San Francisco being a port of embarkation to the Pacific may handle more Gray Air mail letters, because it is suspected that a large percentage of foreign Air mail letters are Gray. The data show that for San Francisco Cancel Air mail, 24% of the letters were Gray as opposed to 3% for the same category in Los Angeles. San Diego, New Orleans, and New York may be of value in testing this hypothesis.

Since there appears to be little difference between Los Angeles and San Francisco with regard to color of envelopes, data from the two cities were combined. Tables 47 through 49 show the combined data and relative frequencies expressed as percentages of the colors. Listed also are 95% confidence limits on the percentages.

Figure 23 shows relative frequency histograms for the color data of San Francisco and Los Angeles combined. On the average, more than 80% of the envelopes in the samples were white.

4. Ratio of hand canceled to machine canceled mail for Washington, D. C.

4.1 Introduction. Approximately 50% of the mail originating in the Washington, D. C. post office is of the "stamped mail" variety. This mail must go through a canceling process before undergoing sorting. The letters may be canceled by

TABLE 47 Percentages and their 95% confidence limits by designated Color of Cancel Regular and Cancel Air mail at S.F. and L.A. combined

	Regular		Air Mail	
Color	Percentage	Confidence Limits for Percentage	Percentage	Confidence Limits for Percentage
White	87%	86%,88%	80%	77%,83%
Yellow	4	3 , 5	2	1 , 3
Red	1	1 , 1	1	0 , 2
Blue	4	3 , 5	11	9 ,14
Gray	3	2 , 4	6	4 , 8
Brown	2	1 , 3	1	0 , 2
Multi-color			1	0 , 2
	101%		102%	

TABLE 48 Percentages and their 95% confidence limits by designated Color of Cull Regular and Cull Air mail at S.F. and L.A. combined

	Regular		Air Mail	
Color	Percentage	Confidence Limits for Percentage	Percentage	Confidence Limits for Percentage
White	84%	83%,85%	72%	67%,76%
Yellow	5	4 , 6	2	1 , 4
Red	1	1 , 1	1	0 , 2
Blue	2	1 , 3	13	10 , 16
Gray	3	2 , 4	7	5 , 10
Brown	6	5 , 7	5	3 , 7
Multi-color				
	101%		100%	

TABLE 49 Percentages and their 95% confidence limits by designated Color of Metered mail at S.F.

Color	Percentage	Confidence Limits for Percentage
White	91%	88%,94%
Yellow	1	0 , 2
Red		
Blue		
Gray	5	3 , 7
Brown	3	2 , 5
Multi-color		
	100%	

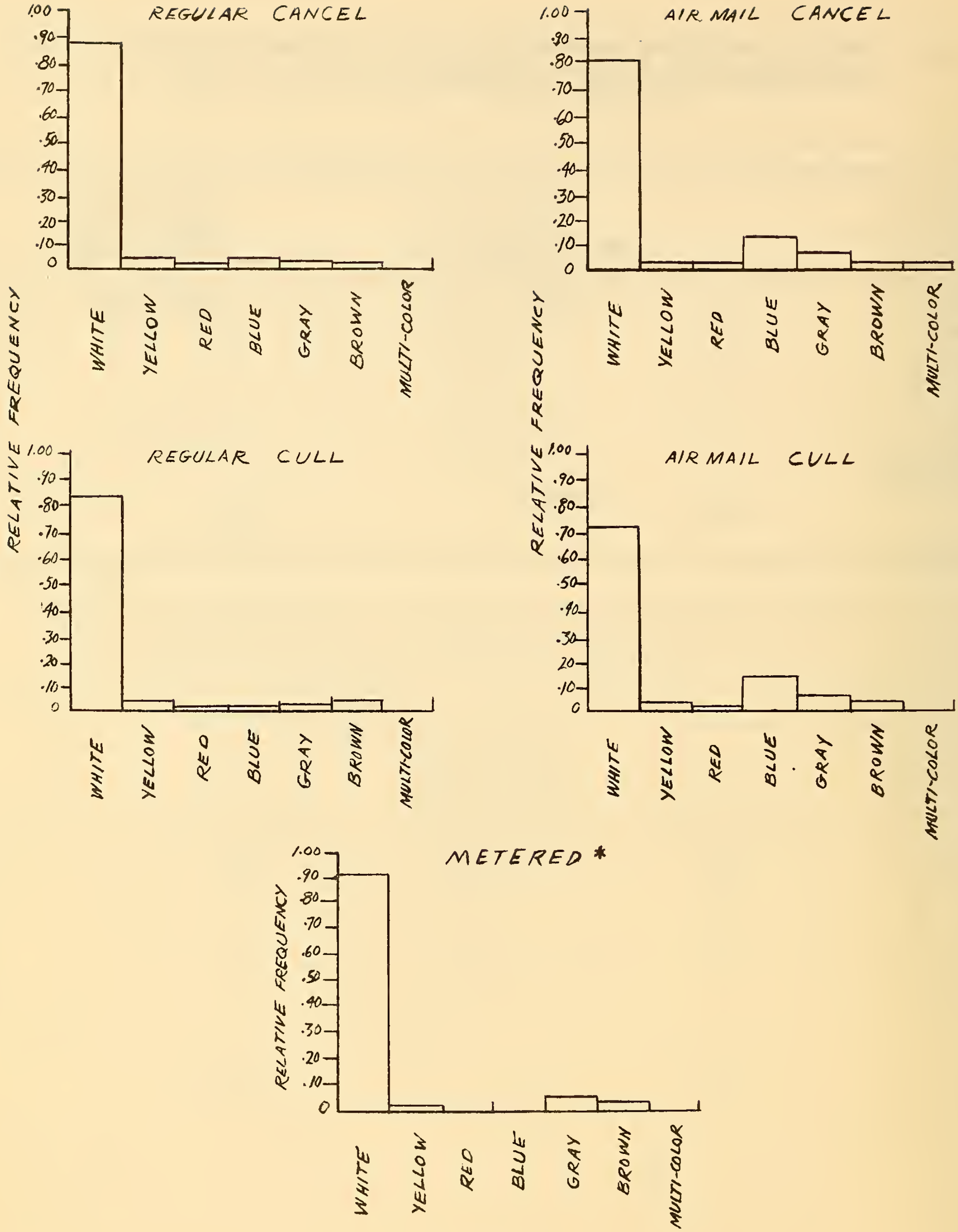


Figure 23

Relative frequency histograms by designated Colors for the combined data of S.F. and L.A.

* - Metered mail applies only to S.F.

machine immediately after leaving the facing tables or they may be canceled by hand, if for various reasons, they cannot pass through canceling machines.

The purpose of the present study was to determine the ratio of hand canceled mail to machine canceled mail.

The data shown in this section were previously presented, together with an initial analysis and conclusion, to the Post Office Department in memorandum form by Dr. Marvin Zelen, NBS, in 1956. Here we present the results of an alternative analysis which, for all practical purposes, are the same as those given earlier. An additional ratio, reflecting the all day period, has also been obtained. No subsequent study of this nature has been made in any other post office. However, the study is included in this report because it represents a simple statistical sampling method for determining ratios previously obtained by complete enumeration.

4.2 Sampling plan and results. At the First Class Hopper, stamped mail which cannot go through the canceling machine is hand canceled. The post office has estimated that the strictly letter size mail which needs to be hand canceled is 1.75% of the total machine cancellations. It was desired to check this figure without making a total count at the First Class Hopper. The sampling procedure was to make a ten minute count of "letter size mail" at the First Class Hopper, extrapolate the average rate per hour , and divide this number by the total volume obtained from the canceling machines for that hour. Thus if Y = number of letters counted in ten minutes, X = total number of machine cancellations for the hour containing that ten minute period, then the ratio

$$R = \frac{6Y}{X}$$

gives the estimated ratio of hand canceled mail to machine canceled mail.

The figures actually obtained, however, were not for <u>strictly</u> letter size mail; the people involved in the actual counting, counted not only letter size mail but also mail which was "slightly larger." This was motivated by their feeling that this "slightly larger size mail" could also be accommodated in any proposed sorting machine. Thus, because of this departure from the original sampling plan, the derived ratios cannot be used to check the post office figure of 1.70%. The results and procedures are included though, to serve as a model for other similar type studies. Table 50 summarizes the original data.

The results of the statistical analyses were that the ratio, expressed as a percentage, of hand canceled mail to machine canceled mail was 2.11% ± 0.21 for A.M. and 3.94% ± 0.88 for P.M. mail. The estimate of the All Day ratio is 2.44% ± 0.41. (See 2.2b of Appendix for the way in which these figures were obtained).

TABLE 50

Summary Data from First Class Hopper

Date	Hand canceled mail		Machine canceled mail		$R = \frac{6Y}{X} \times 100\%$
	Time	No. in Sample	Time	Total Count	
A.M.					
6-4-56	10:34 - 10:44	206	10:00 - 11:00	57,300	2.16%
6-5-56	10:28 - 10:38	184	10:00 - 11:00	48,400	2.28%
6-11-56	10:54 - 11:04	169	10:00 - 11:00	53,200	1.91%
P.M.					
6-5-56	4:55 - 5:05	394	4:00 - 5:00	50,700	4.66%
	5:29 - 5:39	327	5:00 - 6:00	72,700	2.70%
	5:51 - 6.01	617	5:00 - 6:00	72,700	5.09%
	6:14 - 6:24	361	6:00 - 7:00	114,600	1.89%
6-6-56	5:41 - 5:51	687	5:00 - 6:00	65,200	6.32%
	6:50 - 7:00	909	6:00 - 7:00	108,600	5.02%
6-7-56	3:52 - 4:02	155	3:00 - 4:00	32,000	2.91%
	5:45 - 5:55	531	5:00 - 6:00	77,200	4.13%
6-11-56	5:02 - 5:12	410	5:00 - 6:00	78,400	3.14%
	6:45 - 6:55	506	6:00 - 7:00	83,700	3.63%
6-13-56	5:40 - 5:50	548	5:00 - 6:00	71,000	4.63%

5. Study of top and bottom Clearance Space of an addressed envelope

5.1 Introduction. This section is concerned with the Clearance Space on letters from the top of the top line of intelligence to the top edge of the envelope, and from the bottom of the bottom line of intelligence to the bottom edge of the envelope. The data and analyses are presented in memorandum form in Section 5.3 for Washington, D.C. and in Section 5.4 for San Francisco and Los Angeles. These memoranda are detailed and self-explanatory and were submitted to the Post Office Department on April 22, 1957 for Washington, D. C., and November 15, 1957 for Los Angeles and San Francisco. For Washington, D.C. the data were obtained from a random sample of 634 letters selected from the 4,000 letters available on film. For Los Angeles and San Francisco the data were obtained from a random sample of 1285 letters selected from the 10,585 letters also available on film. (Los Angeles 642, San Francisco 643.)

5.2 Sampling procedure. The procedures used in gathering the sample are the same as those given in detail in Section 3.2 of this report. Each letter in the sample was microfilmed for a permanent record. A masking bar was used to blot out the return address and the name of the addressee (see Figure 24). At a later time sub-samples were taken from the microfilm samples and the clearance distances measured and recorded.

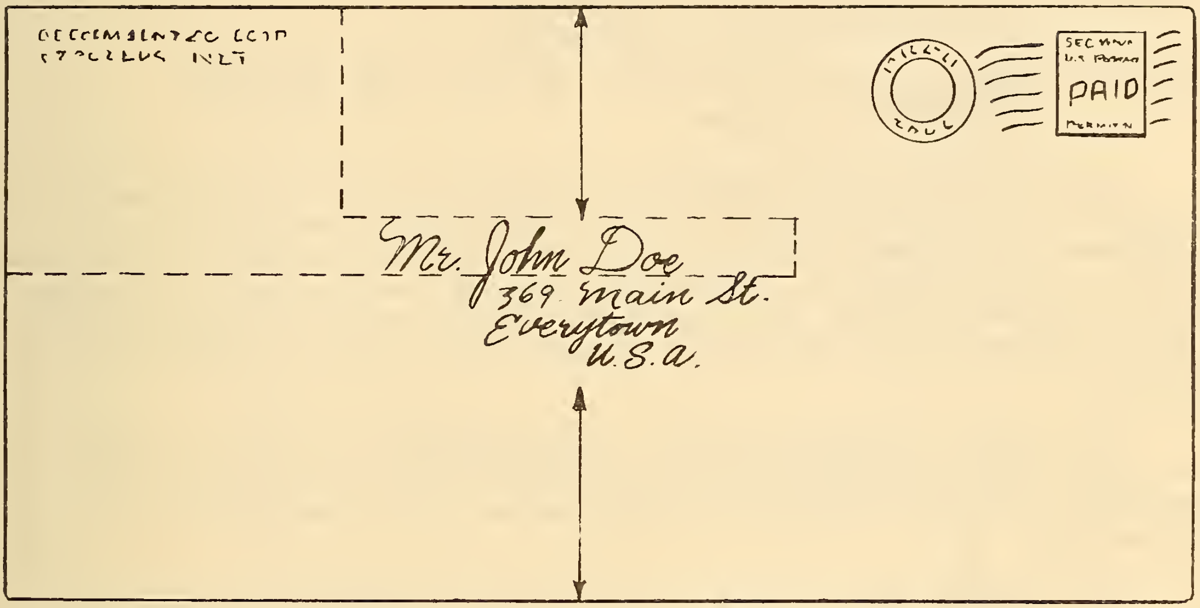


Figure 24

A letter illustrating the distance from the top of the first line of intelligence of the address to the top edge of the envelope, and from the bottom of the last line of intelligence of the address to the bottom edge of the envelope. Dotted line indicates outline of masking bar.

5.3 Washington, D. C. memorandum.

To: C. W. Gray, Director — April 23, 1957
Office of Research and Engineering
Post Office Department

From: N. C. Severo and A. E. Newman
National Bureau of Standards

Subject: Study of Top and Bottom Clearance Space of an Addressed Envelope

Information was requested by the Post Office Department regarding the distribution of distances from the top of an addressed envelope to the top of the first line of intelligence* and from the bottom to the bottom of the last line of intelligence. This information, we understand, is to be used to help in the design of an automatic stamp detecting and cancelling machine.

Data were obtained from a random sample of 634 letters selected from the 4000 letters available to us on film. On the basis of an analysis of these data, we recommend the following:

1) A distance of 3/4 of an inch be used for the top clearance space of an addressed envelope. Actually, the distance 0.757 inch turns out to be the lower 99% tolerance limit with confidence coefficient .95 for the distance from the top of the envelope to the top of the first line of intelligence; i.e., with fairly good betting odds of 19 to 1 it could be expected that 99% of all measurements would be greater than 0.757 inch.

2) No tolerance limit is recommended for the bottom clearance space because from 6% to 11% of all such measurements can reasonably be expected to be less than or equal to 0.2 inch. It turns out that 8.4% of the sample measurements were less than or equal to 0.2 inch and the 95% confidence limits for this estimate are 6% and 11%; i.e., with betting odds of 19 to 1, one would expect the proportion of measurements which are less than or equal to 0.2 inch to be between 6% and 11%.

The original data are included in Tables 51 and 52 Frequency histograms, grouped in intervals of 0.2 inch, are given in Figure 25

* Because of Security reasons, a masking bar was employed to blot out the name of the addressee. Therefore, this distance represents the minimum available distance between the top edge of the masking bar and the top edge of the envelope.

cc: I. Rotkin

TABLE 51

Frequency tabulation of distance from the top edge of the envelope to the top of the first line of intelligence.

Distance in Inches	Frequency
0.1	2
0.2	1
0.3	0
0.4	0
0.5	0
0.6	1
0.7	2
0.8	1
0.9	1
1.0	6
1.1	7
1.2	22
1.3	39
1.4	18
1.5	52
1.6	53
1.7	80
1.8	51
1.9	38
2.0	72
2.1	47
2.2	43
2.3	19
2.4	11
2.5	39
2.6	10
2.7	7
2.8	5
2.9	1
3.0	6
	634 - Total number

Average $\bar{x}$ = 1.842 inches
Standard deviation, s = .431 inches
k = 2.52 for P = .99. α = .95
Lower tolerance limit $\bar{x}$ - ks = .7566

With a reliability of .95, 99% of the mail will have no intelligence at a distance of .75 inches from the top of the envelope.

TABLE 52

Frequency tabulation of distance from bottom edge of the envelope to the bottom of the last line of intelligence for Washington, D. C.

Distance in Inches	Frequency
0.1	35
0.2	18
0.3	30
0.4	26
0.5	33
0.6	19
0.7	47
0.8	42
0.9	11
1.0	49
1.1	32
1.2	36
1.3	35
1.4	32
1.5	62
1.6	25
1.7	35
1.8	18
1.9	14
2.0	22
2.1	2
2.2	6
2.3	4
2.4	0
2.5	0
2.6	0
2.7	0
2.8	1
2.9	0
3.0	0
	634 = Total number

Average, $\bar{x}$ = 1.062 inches
Standard deviation, s = .557 inches
Proportion less than or equal to .2 inches = 8.36%

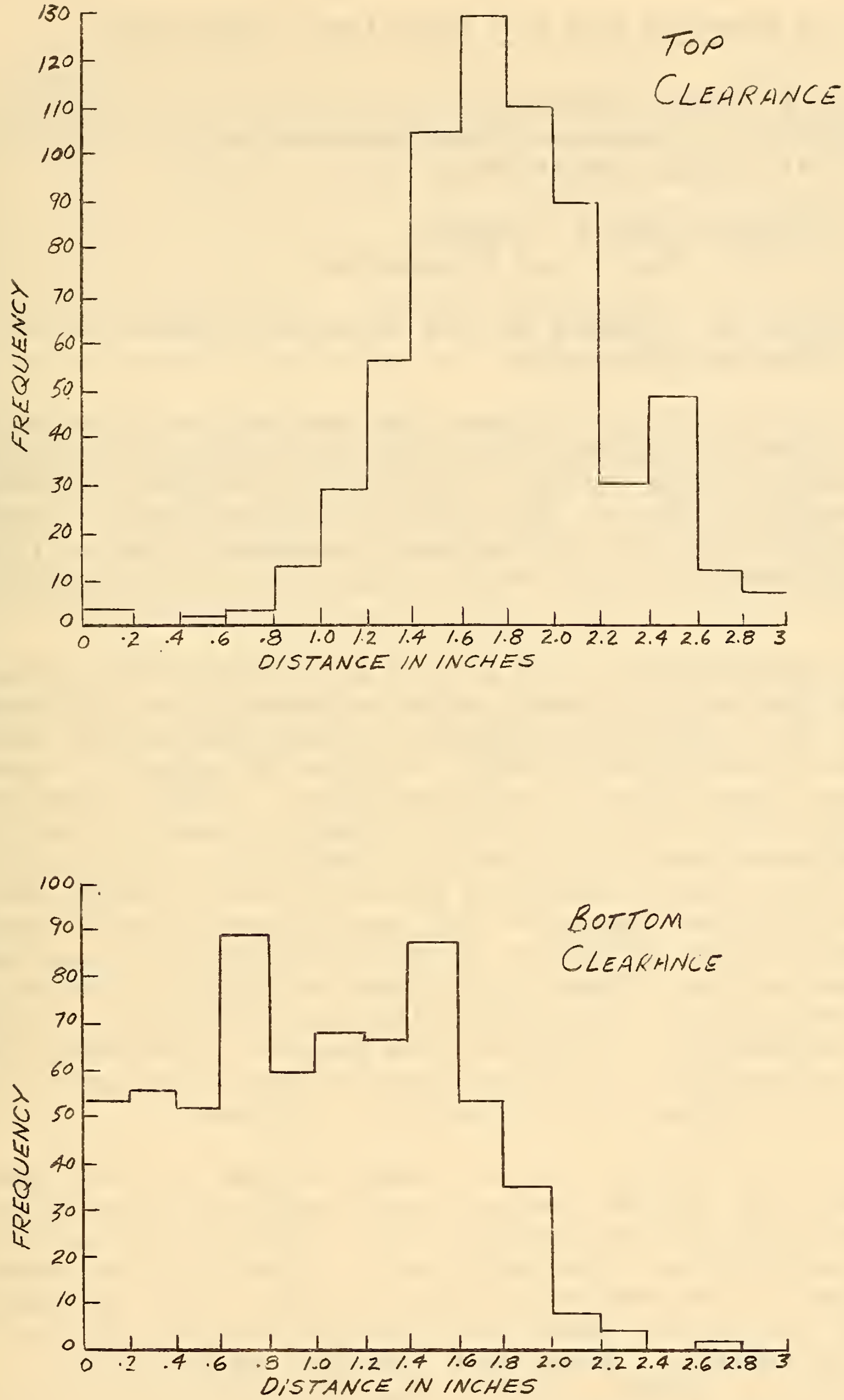


Figure 25

Histograms showing top and bottom clearance space for data from Washington, D. C.

5.4 Los Angeles and San Francisco memorandum.

To: C. W. Gray, Director
Office of Research and Engineering
Post Office Department

15 November 1957

From: N. Severo and A. Newman
National Bureau of Standards

Subject: Study of Top and Bottom Clearance Space of an Addressed Envelope

This report, which concerns top and bottom clearance space for letters sampled in San Francisco and Los Angeles, is a subsequent study to that reported by Severo and Newman in a memorandum to Mr. C. W. Gray on 23 April 1957. The samples for this earlier study were obtained from a filmed record of letters that had been sampled at the Washington Post Office.

It was possible to make the present study more detailed and, in one respect at least, more accurate than the earlier one because the sampling procedure and photographing techniques were designed specifically with the view in mind of answering the questions concerning clearance space. These questions had not been spelled out before the Washington samples were photographed and subsequently measured. Therefore, a detailed comparison of the results reported here for Los Angeles and San Francisco with those reported for Washington is not possible; however, sufficient agreement is manifest between Los Angeles and San Francisco on almost all characteristics, and between the West Coast cities and Washington on those characteristics which are comparable to support the general conclusion that there are no significant differences in the clearance measurements among the three cities thus far studied.

Data were obtained from a random sample of 1285 letters selected from the 10,585 letters available to us on film. (Los Angeles 642, San Francisco 643). Because of security reasons, a masking bar was employed to blot out the name of the addressee. Care was exercised to place the top edge of the masking bar at the exact top edge of the top of the first line of intelligence. Such care was not taken in the Washington, D. C. study. The distances measured are the distance from the top edge of the envelope to the top edge of the masking bar and the distance from the bottom edge of the envelope to the bottom of the last line of intelligence. On the basis of the analysis of the data the following are recommended:

1. A distance of 0.9 of an inch be used for the top clearance space of an addressed envelope. Actually more detailed tolerance limits, corresponding to different types of mail, are listed in Table 53 . For example, it should be noted that for Air Mail alone the corresponding tolerance limit turns out to be .77 inches. These are 99% tolerance limits with confidence coefficient .95 for the top clearance space; i.e., with fairly good betting odds of 19 to 1 it could be expected that 99% of all measurements would be greater than the tolerance limits listed.

2. No tolerance limit is recommended for the bottom clearance space of an addressed envelope for Stamped Mail. A tolerance limit of 0.4 of an inch is recommended for the bottom clearance space of an addressed envelope for Metered Mail. A more detailed analysis is given in Table 54 , where for stamped mail, the estimates and confidence limits for the proportions less than 0.2 of an inch are given.

   The original data are included in Tables 55 and 56 . Frequency histograms of the data, grouped in intervals of 0.3 of an inch given in Figures 26 and 27 .

TABLE 53

Top Clearance Space Tolerance Limits

		n	$\overline{x}$	s^2	Lower Tolerance Limit
(LA+SF)	Meter (L+S)	542	2.1173	0.2181	0.9685
(LA+SF)	Stamped Long	310	2.0803	0.1246	1.1943
(LA+SF)	Stamped Short	334	1.7566	0.1100	0.9274
LA	Air Mail	99	1.8263	0.1546	0.7718
LA	Total	642	1.9955	0.1760	0.9652
SF	Total	643	1.9890	0.1988	0.8938
(LA+SF)	Total	1285	1.9922	0.1812	0.9620

TABLE 54

Bottom Clearance Space Tolerance Limits and Proportion of Distribution Less Than (<) .2 inches

		n	$\bar{x}$	s^2	Lower Tolerance Limit	Proportion < .2"	95% Confidence Limits
LA	Metered (L+S)	238	1.0689	0.1481	.4000		
LA	Stamped Long	158	1.0158	0.2151		5.7%	3%, 11%
LA	Stamped Short	147	0.6810	0.1609		15.0%	9%, 23%
LA	Air Mail	99	0.8515	0.2662		16.2%	9%, 24%
SF	Metered (L+S)	304	1.1984	0.1930	.4000		
SF	Stamped Long	152	1.1118	0.1783		5.9%	2%, 9%
SF	Stamped Short	187	0.6706	0.1290		15.0%	10%, 21%
LA+SF	Stamped Long	310				5.8%	3.5%, 9.0%
LA+SF	Stamped Short	334				15.0%	11%, 20%
LA	TOTAL	642	0.9335	0.2089		7.3%	5%, 9%
SF	TOTAL	643	1.0244	0.2230		5.8%	4.5%, 7.5%

TABLE 55

Frequency Distribution of Clearance Data for Los Angeles

Distance in Inches	TOP CLEARANCE Stamped Long	Stamped Short	Airmail Letters	Metered Letters	Total	BOTTOM CLEARANCE Stamped Long	Stamped Short	Airmail Letters	Metered Letters	Total
.1						6	17	8		31
.2						3	5	8		16
.3						2	11	6		19
.4						7	9	10	1	27
.5			1		1	13	26	4	13	56
.6						6	6	2	15	29
.7						12	14	6	22	54
.8						9	12	5	29	55
.9		2			2	14	9	5	24	52
1.0	1				1	10	12	9	19	50
1.1		2	2		4	12	6	3	26	47
1.2	2	5	4	6	17	11	2	5	28	46
1.3	3	10	3	2	18	11	9	7	10	37
1.4	1	3	4	3	11	13	4	7	12	36
1.5	4	18	12	12	46	5	2	4	9	20
1.6	6	17	7	12	42	11		5	9	25
1.7	8	21	9	10	48	5	3	2	7	17
1.8	13	19	11	8	51	5		1	4	10
1.9	18	13	5	7	43	1		2	6	9
2.0	11	14	15	25	65	1			1	2
2.1	21	6	9	30	66				2	2
2.2	15	10	3	23	51	1				1
2.3	10	2	2	27	41					
2.4	11		5	18	34					
2.5	14	1	3	20	38					
2.6	8	2	4	13	27					
2.7	7	1		12	20				1	1
2.8	3			3	6					
2.9	2			1	3					
3.0				4	4					
3.1				2	2					
3.2										
3.3		1			1					
3.4										
	158	147	99	238	642	158	147	99	238	642

TABLE 56

Frequency Distribution of Clearance Data for San Francisco

Distance in Inches	TOP CLEARANCE Stamped Mail Long	TOP CLEARANCE Stamped Mail Short	TOP CLEARANCE Metered Letters	TOP CLEARANCE Total	BOTTOM CLEARANCE Stamped Mail Long	BOTTOM CLEARANCE Stamped Mail Short	BOTTOM CLEARANCE Metered Letters	BOTTOM CLEARANCE Total
.1					4	16		20
.2					5	12		17
.3					1	12		13
.4					1	13	4	18
.5					4	20	5	29
.6			1	1	4	21	17	42
.7			1	1	12	17	30	59
.8					9	17	27	53
.9			2	2	7	16	20	43
1.0		1	1	2	18	17	25	60
1.1		1		1	8	5	28	41
1.2		8		8	17	6	14	37
1.3		8	8	16	15	9	13	37
1.4	3	12	21	36	12	4	23	39
1.5	6	25	17	48	10	1	36	47
1.6	7	15	7	29	9	1	13	23
1.7	14	20	24	58	12		18	30
1.8	13	30	13	56	3		7	10
1.9	18	8	20	46	1		9	10
2.0	19	25	39	83			5	5
2.1	14	11	25	50			2	2
2.2	13	8	19	40			5	5
2.3	12	7	10	29				
2.4	14	6	19	39			1	1
2.5	10	2	15	27			2	2
2.6	5		12	17				
2.7	2		15	17				
2.8	2		18	20				
2.9			1	1				
3.0			4	4				
3.1			1	1				
3.2			7	7				
3.3			3	3				
3.4								
3.5			1	1				
	152	187	304	643	152	187	304	643

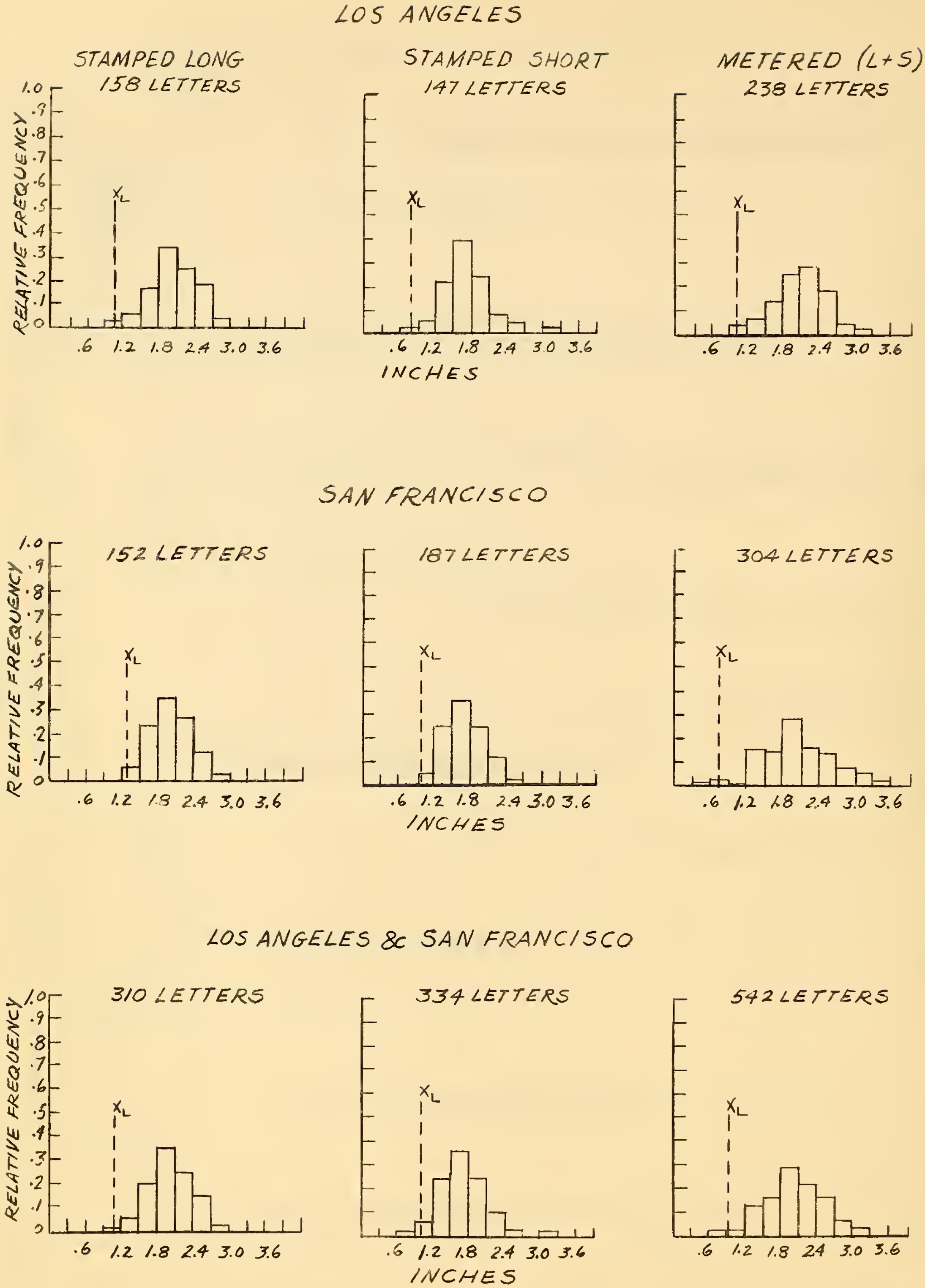


Figure 26.a

Histograms showing top clearance space for data from S.F. and L.A. The vertical scale gives relative frequencies and the horizontal scale gives the distance in inches from top of envelope to top of first line of intelligence.

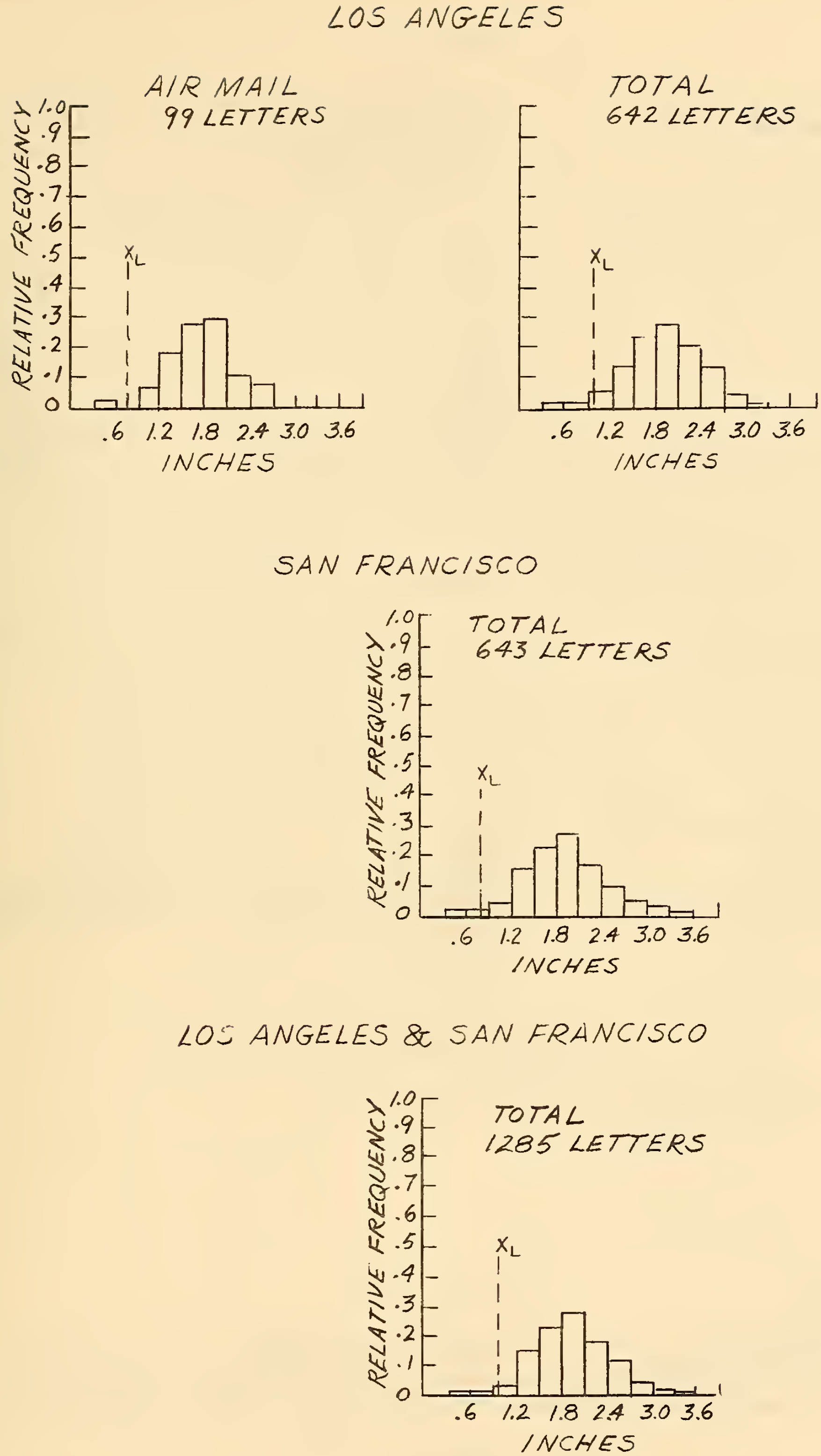


Figure 26.b

Histograms showing top clearance space for data from S.F. and L.A. The vertical scale gives relative frequencies and the horizontal scale gives the distance in inches from top of envelope to top of first line of intelligence.

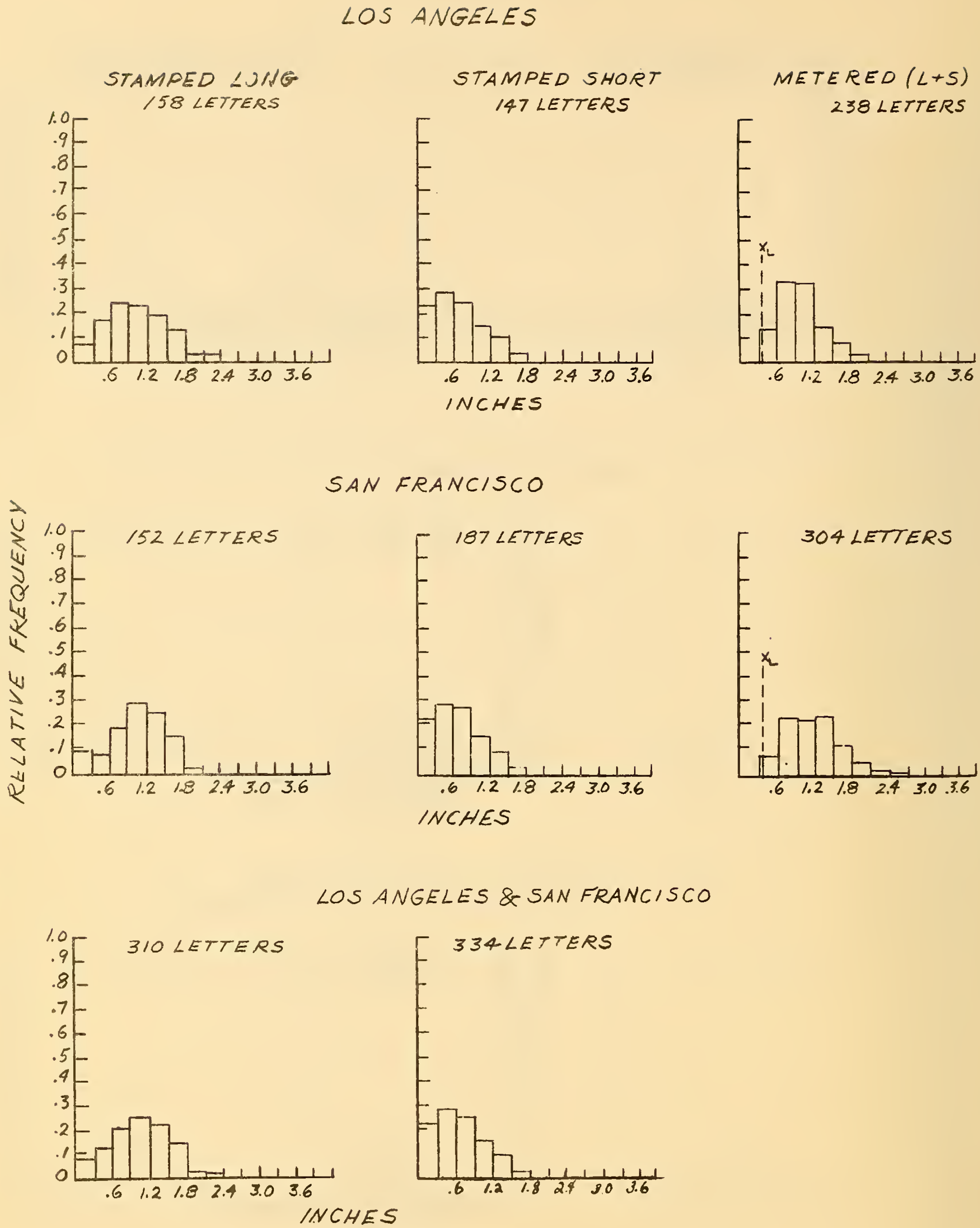


Figure 27.a

Histograms showing botton clearance space for data from S.F. and L.A. The vertical scale gives relative frequencies and the horizontal scale gives the distance in inches from bottom of envelope to bottom of last line of intelligence.

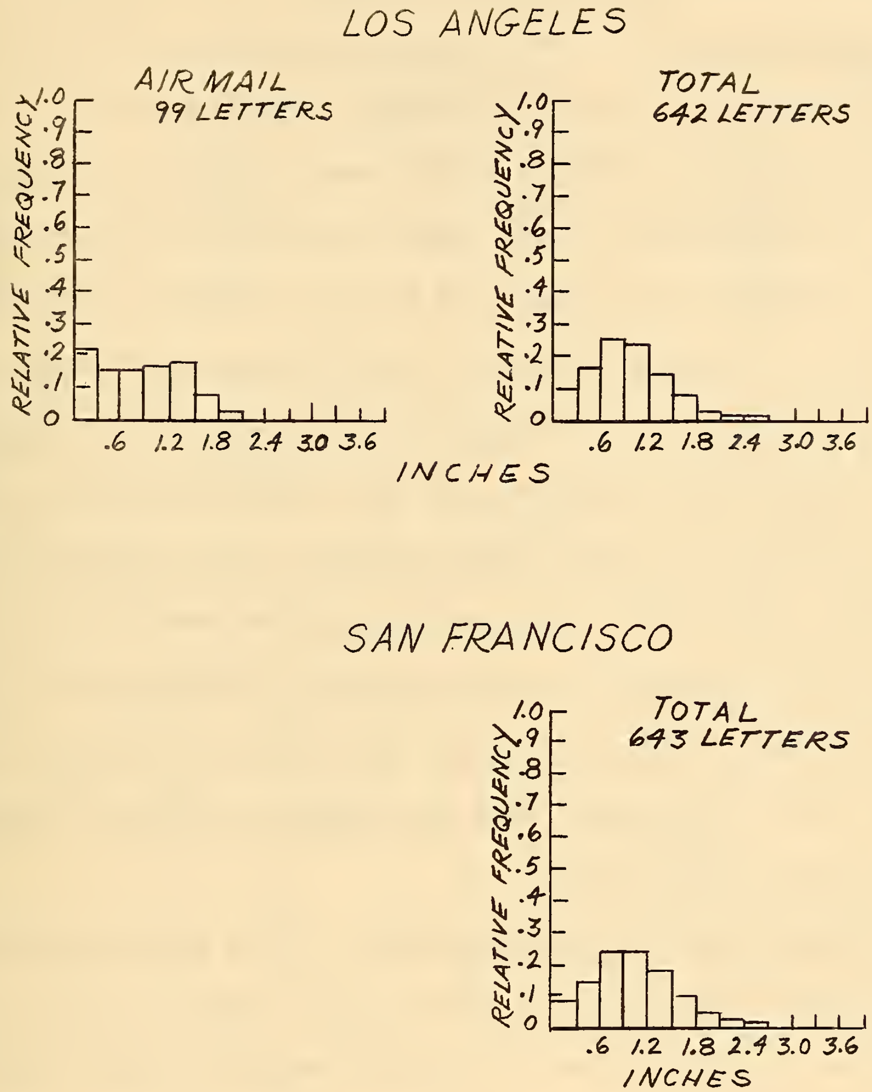


Figure 27.b

Histograms showing bottom clearance space for data from S.F. and L.A. The vertical scale gives relative frequencies and the horizontal scale gives the distance in inches from bottom of envelope to bottom of last line of intelligence.

6. Proportions of Long and Short letters

6.1 Introduction. The nature of handling and distributing letter mail in the post offices sampled was such that separate studies were necessary for Long letters and Short letters. In Washington, D. C., Long and Short letters are canceled on separate machines and hourly readings are made on each machine. A complete enumeration is made each day and the proportions of Long and Short letters are easily obtainable. However, in both San Francisco and Los Angeles, Long and Short letters are canceled on the same machine and no separate data are available. Therefore, the sampling plan described in this section addresses itself to the problem of determining the proportion of Long letters to Long plus Short letters. Samples were taken in San Francisco and Los Angeles and are summarized and analyzed in this section.

6.2 Sample method and procedure. At a predetermined time during the peak period a sample was taken at the stackers adjoining the facing tables. A random selection was made of the facing tables to be sampled. The stackers were first swept clean, then all of the letters accumulating in the stackers for a period of one and a half minutes comprised the sample. Each such sample consisted of approximately 300 letters. The number of Long letters and the number of Short letters contained in each sample were recorded. Samples were collected during each of the two peak periods on each day sampled.

	San Francisco		Los Angeles	
	Percent Long	Confidence Limits on Percent Long	Percent Long	Confidence Limits on Percent Long
A.M. Period	26%	21%, 31%	31%	27%, 36%
P.M. Period	51%	46%, 56%	48%	43%, 53%
All Day Period	46%	41%, 50%	45%	41%, 49%

6.3 <u>Analysis</u>. The data obtained by the method described in Section 6.2 are presented in Table 57 . These data are given on a daily basis so that each number represents a sum of all the samples taken throughout the day. Summarized here are the ratios of Long to Long plus Short letters for (a) the A.M. period, defined from 8:00 A.M. to 4:00 P.M.; (b) the P.M. period, defined from 4:00 P.M. to 11:00 P.M.; and (c) the All Day period, defined from 8:00 A.M. to 11:00 P.M.

In order to calculate the All Day estimates of the ratio of Long to Long plus Short, it was necessary to use certain weighting factors which reflect the A.M. and P.M. volume of mail. The weighting factors used are

$$\alpha_1 = \frac{V_A}{V_A+V_P}$$

where V_A and V_P represent the volume of A.M. and P.M. mail, respectively, and $1-\alpha_1 = \alpha_2$. Volume figures supplied by the respective post offices indicated that

TABLE 57

Sample data showing proportions of Long to Long plus Short letters by A.M. and P.M. periods for S.F. and L.A.

	A.M. Period				P.M. Period			
Date	Long	Short	Total	$\frac{L}{L+S}$ x 100%	Long	Short	Total	$\frac{L}{L+S}$ x 100%
SAN FRANCISCO:								
6/21	44	135	179	25%	706	454	1160	61%
6/24	235	918	1153	20%	713	317	1030	69%
6/25	437	1093	1530	29%	1028	840	1868	55%
6/26	142	447	589	24%	808	861	1669	48%
6/27	328	674	1002	33%	704	979	1683	42%
6/28	85	298	383	22%	327	654	981	33%
TOTAL	1271	3565	4836	26%	4286	4105	3391	51%
LOS ANGELES:								
6/12					792	1053	1845	43%
6/13	300	746	1046	29%	334	303	637	52%
6/14	372	840	1212	31%	679	563	1242	55%
6/17	378	1100	1478	26%	718	649	1367	53%
6/18	469	641	1110	42%	361	524	885	41%
TOTAL	1519	3327	4846	31%	2884	3092	5976	48%

$$a_1 = \begin{cases} .222 & \text{for San Francisco} \\ .205 & \text{for Los Angeles} \end{cases}$$

The 95% confidence limits given in the table were computed by using the formulae given in 2.2c of the Appendix.

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[2] W. G. Cochran, F. Mosteller, and J. Tukey, "Principles of Sampling," Journal of the Am. Stat. Assoc., Volume 49, (1954), pp. 13-35.

[3] H. Cramer, Mathematical Methods of Statistics, Princeton University Press, Princeton, New Jersey, 1951, p. 353.

[4] C. Eisenhart, M. W. Hastey, and W. A. Wallis, Techniques of Statistical Analysis, McGraw-Hill Book Company, Inc., New York, 1947, pp. 97-108.

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[6] R. B. Murphy, "Non-Parametric Tolerance Limits," Annals of Mathematical Statistics, Volume 19, (1948), pp. 581-589.

[7] E. S. Pearson and H. O. Hartley, Biometrika Tables for Statisticians, Volume I, The University Press, Cambridge, England, 1954, pp. 204-205.

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Appendix

1. Tests

1.1 Control Charts

The limits here have been calculated by using estimates of the standard deviation which are based on the range of the sample averages. For detailed explanation of control charts see Grant [5].

1.2 Analysis of Variance

An analysis of variance, weighted according to the number of samples in each group, was used throughout. See Anderson and Bancroft [1].

1.3 Kolmogorov-Smirnov Test

A straightforward application of the Kolmogorov-Smirnov test was used. See Siegel [8].

2. Formulae

2.1 Tolerance Limits

a) Normal Theory. This was applied in the Clearance Space study, Section 5 , following [4].

b) Non-Parametric-Order Statistics. This method was used in the Letter size Characteristic Study, Section following [6]. Several approximations, involving a normal approximation to the Beta distribution were used. These are

Given: $x_1 \leq x_2 \leq \cdots \leq x_n$

Statement: $100\beta\%$ of population lies between (x_r, x_{n-r+1}) with probability α.

Formula: For $\alpha = .95$ (for large n)

$$m = n+1 - n\beta - 1.64\sqrt{n\beta(1-\beta)}$$

where $m = r+s$

Statement: $100\beta\%$ of population lies between $(-\infty, x_r)$ with probability α.

Formula: For $\alpha = .95$ (for large n)

$$r = n\beta + 1.64\sqrt{n\beta(1-\beta)}$$

2.2 Confidence Limits

a) Confidence limits on proportions. These limits were obtained by using the Clopper-Pearson charts available in [7].

b) Confidence limits on ratios of hand to machine canceled mail. Let (x_{i1}, y_{i1}), where $i=1,2,\ldots,n_1$, designate the number of machine canceled and hand canceled letters on an hourly basis respectively for the A.M. period. Then the ratio of hand canceled to machine canceled mail for the A.M. period is

$$R_1 = \frac{\sum_{i=1}^{n_1} y_{i1}}{\sum_{i=1}^{n_1} x_{i1}} .$$

Similarly, by characterizing the P.M. period with the subscript 2, the P.M. period ratio becomes

$$R_2 = \frac{\sum_{i=1}^{n_2} y_{i2}}{\sum_{i=1}^{n_2} x_{i2}} .$$

Then by a straight forward application of the "propagation of error" formula [3] the variance of R_j, $j=1,2$, may be estimated by

$$\hat{\sigma}^2_{R_j} = \frac{1}{n_j} \left\{ \left(\frac{y_{.j}}{x_{.j}} \right)^2 \left[\frac{\hat{\sigma}^2_{y_j}}{y^2_{.j}} + \frac{\hat{\sigma}^2_{x_j}}{x^2_{.j}} - \frac{2r_j \; \hat{\sigma}_{y_j} \; \hat{\sigma}_{x_j}}{y_{.j} \; x_{.j}} \right] \right\},$$

where, for $j=1,2$,

$$y_{.j} = \frac{\sum_{i=1}^{n_j} y_{ij}}{n_j} ,$$

$$x_{.j} = \frac{\sum_{i=1}^{n_j} x_{ij}}{n_j} ,$$

$$\hat{\sigma}^2_{y_j} = \frac{\sum_{i=1}^{n_j} (y_{ij} - y_{.j})^2}{n_j - 1} ,$$

$$\hat{\sigma}^2_{x_j} = \frac{\sum_{i=1}^{n_j} (x_{ij} - x_{.j})^2}{n_j - 1} ,$$

$$r_j \hat{\sigma}_{y_j} \hat{\sigma}_{x_j} = \frac{\sum_{i=1}^{n_j} (y_{ij} - y_{.j}) (x_{ij} - x_{.j})}{n_j - 1}$$

The variance formula for R_j was derived under the assumption that the numerator and denominator of the ratio are functionally independent. Assuming approximate normality of the sums comprising the numerators and denominators, the γ-confidence limits on the A.M. or P.M. ratio (i.e., corresponding to j=1,2 respectively) are then determined by

$$R_j \pm z \hat{\sigma}_{R_j} ,$$

where z is the one-tail $\frac{1}{2}(1-\gamma)$-percentage point of the Gaussian distribution.

The variance of the weighted average (which is an estimate of the All Day ratio)

$$R = \alpha_1 R_1 + \alpha_2 R_2 ,$$

where α_1 and α_2 are appropriate weighting constants determined in a similar manner to that described in Section 6, may be written as

$$\text{Var } R = \alpha_1^2 \text{ Var } R_1 + \alpha_2^2 \text{ Var } R_2 .$$

Here the α_j are assumed constant and their values are α_1=0.312 and α_2=0.688. Thus an estimate of Var R may be taken as

$$\hat{\sigma}^2_R = \alpha_1^2 \hat{\sigma}^2_{R_1} + \alpha_2^2 \hat{\sigma}^2_{R_2} .$$

The confidence limits on the All Day ratio of hand to machine canceled letters are then determined by

$$R \pm z \hat{\sigma}_R ,$$

where again z is defined as above.

c) Confidence limits on the ratio of Long to Long plus Short letters. Let the number of Long and Short letters collected in each A.M. minute and a half sample be designated by (L_{i1}, S_{i1}), where $i=1,2,\ldots,n_1$. Similarly let (L_{i2}, S_{i2}), $i=1,2,\ldots,n_2$, designate the number of Long and Short letters collected in each P.M. minute and a half sample. Furthermore let

$$N_{ij} = L_{ij} + S_{ij}, \quad i=1,2,\ldots,n_j \text{ and } j=1,2.$$

Then by a straight forward application of the "propagation of error" formula [3] the variance of

$$\mu_j = \frac{\sum_{i=1}^{n_j} L_{ij}}{\sum_{i=1}^{n_j} N_{ij}} , \qquad j=1,2$$

may be estimated by

$$\hat{\sigma}^2_{\mu_j} = \frac{1}{n_j} \left\{ \frac{S^2_{.j}\hat{\sigma}^2_{L_j} + L^2_{.j}\hat{\sigma}^2_{S_j} - 2S_{.j}L_{.j}r_j\hat{\sigma}_{L_j}\hat{\sigma}_{S_j}}{N^4_{.j}} \right\},$$

where, for $j=1,2$,

$$S_{.j} = \frac{\sum_{i=1}^{n_j} S_{ij}}{n_j} ,$$

$$L_{.j} = \frac{\sum_{i=1}^{n_j} L_{ij}}{n_j} ,$$

$$N_{.j} = S_{.j} + L_{.j} \quad ,$$

$$\hat{\sigma}^2_{S_j} = \frac{\sum_{i=1}^{n_j} (S_{ij} - S_{.j})^2}{n_j - 1} \quad ,$$

$$\hat{\sigma}^2_{L_j} = \frac{\sum_{i=1}^{n_j} (L_{ij} - L_{,j})^2}{n_j - 1} \quad ,$$

$$r_j \hat{\sigma}_{L_j} \hat{\sigma}_{S_j} = \frac{\sum_{i=1}^{n_j} (S_{ij} - S_{.j})(L_{ij} - L_{.j})}{n_j - 1} \quad .$$

(The formula for Var μ_j differs from that given in Appendix 2.2b for Var R_j because the numerator and denominator of μ_j are functionally dependent.) The γ-confidence limits on the A.M. and P.M. ratios (i.e., corresponding to j=1,2, respectively) are then determined by

$$\mu_j \pm z \, \hat{\sigma}_{\mu_j} \quad ,$$

where z is the one-tail $\frac{1}{2}$ $(1-\gamma)$-percentage point of the Gaussian distribution.

The variance of the weighted average (which is an estimate of the All Day ratio)

$$W = \alpha_1\mu_1 + \alpha_2\mu_2 \quad ,$$

where α_1 and α_2 are defined in Section 6 and assumed here to be constant, and the confidence limits for the All Day ratio are obtained in a similar manner to that discussed in the above Appendix 2.2b.

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