Using Double Sampling Inspection in a Manufacturing Plant

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THE necessity for quality control in a manufacturing plant arises from the fact that all units of product cannot be made identical. To limit variations and attain controlled uniformity some sort of inspection must be established. It has been the experience of the Western Electric Company that quality control may be attained most economically by the use of a sampling inspection wherein only a portion of the entire output is examined for desired quality characteristics.

Advantages which have been gained through the use of sampling inspection, and with no adverse effect on previously existing quality levels, are: a reduction in the cost of inspection by economies in inspection time; a reduction in the amount of scrap produced by making available for supervisory action useful records of the results of inspection; and as an end result, the attainment of uniform quality of a satisfactory level.

It is the purpose of this paper to provide a detailed method of procedure that has proved successful in establishing and maintaining one type of sampling—the "Average Outgoing Quality Limit" Double Sampling Plan. Statistically determined tables of lot sizes and corresponding sample sizes which guarantee a certain degree of protection have been used by the Western Electric Company for approximately fifteen years. They were furnished by the Bell Telephone Laboratories and have recently been made generally available in an article published in the January 1941 issue of the Bell System Technical Journal.[1] A typical sampling table, reproduced from the preceding article, is shown in Fig. 1.

Briefly stated, the AOQL Double Sampling Plan involves the examination on a "go—no go" basis of a specified number of articles taken at random from a large group. The acceptance or rejection of this group is usually made on the basis of results obtained from the first sample alone. How-

[1] The AOQL Double Sampling Tables specifically referred to in the present article are Tables DA-0.1 to DA-10.0 shown on pages 49-61, inclusive, of a preceding article: H. F. Dodge and H. G. Romig, "Single Sampling and Double Sampling Inspection Tables", *Bell Sys. Tech. Jour.*, pp. 1–61, Jan. 1941. These tables give sample sizes and allowable numbers of defectives for a variety of AOQL values, lot sizes, and process average values. The sampling table reproduced in Fig. 1 is based on an AOQL value of 1.5 per cent defective. In tables prepared for shop use, it has been found preferable to use a notation slightly different from that shown in Fig. 1, specifically to use AN instead of c to represent "allowable number of defectives" and to use SS instead of n to represent "sample size". The shop notation is used in the present article. It should be noted that, in the original article, C was generally referred to as an allowable number of "defects", since primary attention was given to inspection of a single characteristic. See footnote 2 for explanation of the terms "defective" and "defect".

TABLE IV CONT'D: DOUBLE SAMPLING LOT INSPECTION TABLES—BASED ON STATED VALUES OF "AVERAGE OUTGOING QUALITY LIMIT"

TABLE DA-1.5

AVERAGE OUTGOING QUALITY LIMIT = 1.5%

Process Average % 0–.03

Lot Size	Trial 1 n_1	Trial 1 c_1	Trial 2 n_2	Trial 2 n_1+n_2	Trial 2 c_2	p_t %
1–15	All	0	–	–	–	–
16–50	16	0	–	–	–	11.6
51–75	23	0	11	34	1	10.5
76–100	26	0	14	40	1	9.4
101–200	31	0	18	49	1	8.4
201–300	33	0	22	55	1	8.0
301–400	34	0	21	55	1	7.9
401–500	35	0	20	55	1	7.8
501–600	35	0	20	55	1	7.8
601–800	35	0	20	55	1	7.8
801–1000	36	0	19	55	1	7.8
1001–2000	44	0	51	95	2	6.3
2001–3000	45	0	50	95	2	6.2
3001–4000	45	0	50	95	2	6.2
4001–5000	45	0	50	95	2	6.2
5001–7000	46	0	54	100	2	6.1
7001–10,000	46	0	54	100	2	6.1
10,001–20,000	46	0	54	100	2	6.1
20,001–50,000	47	0	53	100	2	6.1
50,001–100,000	47	0	53	100	2	6.1

Process Average % .04–.30

Lot Size	Trial 1 n_1	Trial 1 c_1	Trial 2 n_2	Trial 2 n_1+n_2	Trial 2 c_2	p_t %
1–15	All	0	–	–	–	–
16–50	16	0	–	–	–	11.6
51–75	23	0	11	34	1	10.5
76–100	26	0	14	40	1	9.4
101–200	31	0	18	49	1	8.4
201–300	33	0	22	55	1	8.0
301–400	34	0	21	55	1	7.9
401–500	35	0	20	55	1	7.8
501–600	40	0	45	85	2	6.8
601–800	41	0	49	90	2	6.7
801–1000	42	0	48	90	2	6.5
1001–2000	44	0	51	95	2	6.3
2001–3000	45	0	50	95	2	6.2
3001–4000	50	0	85	135	3	5.5
4001–5000	50	0	85	135	3	5.5
5001–7000	50	0	90	140	3	5.4
7001–10,000	50	0	90	140	3	5.4
10,001–20,000	50	0	90	140	3	5.4
20,001–50,000	55	0	125	180	4	5.0
50,001–100,000	55	0	130	185	4	4.9

Process Average % .31–.60

Lot Size	Trial 1 n_1	Trial 1 c_1	Trial 2 n_2	Trial 2 n_1+n_2	Trial 2 c_2	p_t %
1–15	All	0	–	–	–	–
16–50	16	0	–	–	–	11.6
51–75	23	0	11	34	1	10.5
76–100	26	0	14	40	1	9.4
101–200	31	0	18	49	1	8.4
201–300	38	0	37	75	2	7.0
301–400	39	0	41	80	2	6.9
401–500	39	0	46	85	2	6.9
501–600	40	0	45	85	2	6.8
601–800	46	0	74	120	3	6.0
801–1000	47	0	78	125	3	5.9
1001–2000	49	0	81	130	3	5.7
2001–3000	55	0	110	165	4	5.3
3001–4000	55	0	115	170	4	5.2
4001–5000	55	0	120	175	4	5.1
5001–7000	60	0	155	215	5	4.7
7001–10,000	60	0	160	220	5	4.6
10,001–20,000	60	0	165	225	5	4.5
20,001–50,000	65	0	195	260	6	4.4
50,001–100,000	115	1	235	350	8	4.0

Process Average % .61–.90

Lot Size	Trial 1 n_1	Trial 1 c_1	Trial 2 n_2	Trial 2 n_1+n_2	Trial 2 c_2	p_t %
1–15	All	0	–	–	–	–
16–50	16	0	–	–	–	11.6
51–75	23	0	11	34	1	10.5
76–100	26	0	14	40	1	9.4
101–200	35	0	35	70	2	7.5
201–300	38	0	37	75	2	7.0
301–400	39	0	41	80	2	6.9
401–500	44	0	71	115	3	6.1
501–600	44	0	71	115	3	6.1
601–800	46	0	74	120	3	6.0
801–1000	47	0	78	125	3	5.9
1001–2000	55	0	105	160	4	5.4
2001–3000	100	1	145	245	6	4.6
3001–4000	105	1	190	295	7	4.3
4001–5000	105	1	190	295	7	4.3
5001–7000	110	1	225	335	8	4.2
7001–10,000	115	1	280	395	9	3.9
10,001–20,000	120	1	315	435	10	3.8
20,001–50,000	165	2	350	515	12	3.7
50,001–100,000	175	2	440	615	14	3.5

Process Average % .91–1.20

Lot Size	Trial 1 n_1	Trial 1 c_1	Trial 2 n_2	Trial 2 n_1+n_2	Trial 2 c_2	p_t %
1–15	All	0	–	–	–	–
16–50	16	0	–	–	–	11.6
51–75	23	0	11	34	1	10.5
76–100	26	0	14	40	1	9.4
101–200	35	0	35	70	2	7.5
201–300	38	0	37	75	2	7.0
301–400	42	0	63	105	3	6.3
401–500	44	0	71	115	3	6.1
501–600	44	0	71	115	3	6.1
601–800	49	0	101	150	4	5.6
801–1000	50	0	105	155	4	5.5
1001–2000	95	1	175	270	7	4.6
2001–3000	110	1	255	365	9	4.1
3001–4000	160	2	300	460	11	3.8
4001–5000	165	2	340	505	12	3.7
5001–7000	165	2	375	540	13	3.7
7001–10,000	170	2	420	590	14	3.6
10,001–20,000	210	3	420	630	15	3.6
20,001–50,000	225	3	640	865	20	3.3
50,001–100,000	275	4	725	1000	23	3.2

Process Average % 1.21–1.50

Lot Size	Trial 1 n_1	Trial 1 c_1	Trial 2 n_2	Trial 2 n_1+n_2	Trial 2 c_2	p_t %
1–15	All	0	–	–	–	–
16–50	16	0	–	–	–	11.6
51–75	23	0	11	34	1	10.5
76–100	26	0	14	40	1	9.4
101–200	35	0	35	70	2	7.5
201–300	40	0	60	100	3	6.6
301–400	42	0	63	105	3	6.3
401–500	46	0	94	140	4	5.8
501–600	47	0	98	145	4	5.7
601–800	85	1	125	210	6	5.0
801–1000	90	1	125	215	6	4.9
1001–2000	100	1	230	330	9	4.4
2001–3000	155	2	345	500	13	3.9
3001–4000	205	3	405	610	15	3.6
4001–5000	250	4	480	730	18	3.5
5001–7000	310	5	610	920	22	3.3
7001–10,000	360	6	660	1020	24	3.2
10,001–20,000	415	7	835	1250	29	3.1
20,001–50,000	510	9	1130	1640	38	3.0
50,001–100,000	570	10	1400	1970	45	2.9

Fig. 1—Typical sampling table for the AOQL double sampling plan; AOQL = 1.5 per cent defective
(Reproduced from article referred to in footnote on page 37)

ever, if the results from the first sample are not conclusive, an additional sample is examined before disposition of the lot is made.

The particular type of articles to which this plan has been applied are products consisting of individual parts, sub-assemblies, or completed apparatus, which, at the various stages of production where control is necessary, are the result of repetitive operations capable of considerable uniformity. The plan has also been applied to some extent on completed products and purchased materials where there is evidence that the product is of reasonable uniformity even though the quality history is meager or unavailable.

1. Steps in Setting up a Double Sampling Lot Inspection Plan

1.1 *Analysis of the Production Process*

In order to determine the applicability of the Double Sampling Plan to existing inspection operations it is necessary to examine the manufacturing and inspection processes and all data available regarding past quality performance, such as records of per cent defective, consumers' complaints, etc. The following outline should serve not only as a measuring stick to determine the applicability of Double Sampling but also as an index of the conditions to be met for the successful use of Double Sampling with any inspection operation.

1.11 The *lot*, or group of articles to be examined, should consist of product which is available in its entirety for acceptance or rejection at one time. For sampling purposes, the lot should have characteristics which are the result of a common system of causes. By this it is meant that the lot should, as far as possible, consist of articles made from relatively uniform raw material by operators of equivalent skill and by machines or methods of equivalent precision. If there is evidence of appreciable variation between corresponding machines, operators, or materials, it is desirable to confine a lot to the output of one machine, one operator, or one batch of material, in order to isolate a uniform group of product suitable for sampling inspection.

In brief, Double Sampling may be applied to the output of any repetitive unit operation capable of sufficient uniformity. However, unless immediately essential for economic reasons, it need not be applied at the particular time such an operation is completed, provided succeeding operations do not modify the inspection item under consideration.

1.12 In order to gain the maximum advantage from the use of Double Sampling, it is necessary that lots be as large as the limitation of uniformity will allow so that protection and control may be achieved with a minimum sample size relative to the number of units in the lot. The fact that proportionately smaller sample sizes are used with the larger lot sizes may be seen by reference to the Sampling Table of Fig. 1.

In sampling from larger lots it becomes *increasingly important* in practice to observe certain precautions in order to take care of instances where the lot may not be homogeneous; specifically, each sample should be a group of articles *taken at random from different locations throughout the lot* so that it will represent an impartial cross section of the lot.

1.13 It is necessary for the successful operation of any sampling inspection that at all times there be a known standard of acceptability for the individual article, that is, a definite description of the requirement for each inspection item and reliable measuring equipment against which product may be conclusively checked. Practically, this condition will be realized when the characteristic is defined in such a manner that different observers will obtain consistent results.

1.14 The theoretical background of the plan assumes the repair or elimination of all defectives[2] in samples of accepted lots, as well as all defectives in rejected lots before such lots are passed.

In order to accomplish this, close cooperation between production and inspection personnel is required in assuring that rejected lots are thoroughly cleared of all defectives, since failure to comply with this fundamental part of the procedure destroys the very foundation of the plan.

1.2 *Selection of Proper Double Sampling Table*

Tables are provided for a variety of Average Outgoing Quality Limit (AOQL) values and Process Average classes. The AOQL value is the maximum value of average per cent defective in the product after inspection, which the sampling plan will assure over a long period of time, no matter how defective the product submitted for inspection may be. The process average is the normal per cent defective which is to be expected from the process.

To determine what AOQL valve should be adopted, it is necessary to decide upon a maximum average per cent defective which may be permitted in the product without serious consequences to the user. Product which is of such a nature that defects will be eliminated in subsequent operations may be assigned a rather generous AOQL, and conversely, product which by its relation to the entire assembly may cause considerable inconvenience

[2] A *defective* is defined as an individual article that fails to meet the requirements for one or more inspection items. A *defect*, however, is defined as a failure to meet a requirement for a single quality characteristic for which inspection is made. It follows that when several characteristics are inspected, an individual article may have several *defects*, yet be only a single *defective*.

if it fails to meet requirements, usually warrants a strict AOQL. A rather generous AOQL may be assigned to inspection features which are considered relatively unimportant. In other cases the use of sampling may be definitely inadvisable due to the importance of the requirement from a functional standpoint or from the standpoint of the possible effect of a failure upon the safety or health of an individual.

As a guide in the selection of the AOQL, the following table is given, showing values that have been found to be satisfactory for the product listed. These percentage values of AOQL represent per cent of articles defective; if more than one defect is found on an article, the article is counted as one defective. Here, as elsewhere throughout the paper, all figures relate to number of defectives and per cent of articles defective rather than number of defects.

Description	*Requirements*	*AOQL*
Machine Screws	5 Dimensions	2.0%
Hexagon Nuts	Visual Inspection after Zinc Plating	2.0%
Twin Eyelets	6 Dimensions and 4 Visual Requirements	3.0%
Relay Coils*	Inductance and Electrical Breakdown	1.0%
Misc. Completed Electrical Apparatus	Resistance	.5%

The process average is commonly determined by summarizing the results of the first samples inspected during a representative period and may usually be obtained if there has been a previous inspection with associated records. In case suitable records are not available, an approximation may be made on the basis of an examination of a number of random samples selected from product of current manufacture. This will be a tentative figure and may require revision when data accumulated from the operation of the Double Sampling Plan are available.

1.3 *Issuance of the Inspection Layout—Fig. 2*

After the AOQL value has been established, definite instructions in the form of a Sampling Layout (See Fig. 2) should be provided for the use of the inspector. The layout should contain a list of the inspection items for which inspection is required. It should also contain a copy of the sampling table selected, a description of the material to be inspected, AOQL value, process average and other information which is of importance either in using or in maintaining the Double Sampling Plan.

* This is a process check for these requirements which is supplemented by another sampling inspection after assembly.

HL 3340-R (5-40)

LAYOUT FOR STATISTICAL SAMPLING INSPECTION

LAYOUT NO. X

ISSUE NO. X DATE X

MATERIAL INSPECTED: LAMPS — CODE OR P P NO.: X

MATERIAL FROM OPERATING DEPT NO: XX — PROCESS AVERAGE CLASS: .31-.60% — A.O.Q.L.: 1.5 %

OPERATING DEPT OPERATIONS: Assembly

FOR USE BY INSP SECT: X — AUTHORIZED AND APPROVED BY: X — APPROVAL DATE: X

Sampling Table						INSPECTION OPERATIONS
	1st Sample		2nd Sample			
Lot Size	SS	AN	Add	SS	AN	
1-15	All	0	-	-	-	Gage for overall length
16-50	16	0	-	-	-	and distance from end of
51-75	23	0	11	34	1	terminal to end of bulb.
76-100	26	0	14	40	1	
101-200	31	0	18	49	1	
201-300	38	0	37	75	2	
301-400	39	0	41	80	2	
401-500	39	0	46	85	2	
501-600	40	0	45	85	2	
601-800	46	0	74	120	3	
801-1000	47	0	78	125	3	
1001-2000	49	0	81	130	3	
2001-3000	55	0	110	165	4	
3001-4000	55	0	115	170	4	
4001-5000	55	0	120	175	4	
5001-7000	60	0	155	215	5	
7001-10000	60	0	160	220	5	
10001-20000	60	0	165	225	5	

MATERIAL TO BE USED ON: X

PROCESS AVERAGE ACTUAL RECORDS DATED

.557 %	%	%	%
FROM 7-6-40	FROM	FROM	FROM
TO 12-28-40	TO	TO	TO

LAYOUT ISSUED BY: X

APPROX. ANNUAL OUTPUT: X — USUAL LOT SIZE: 4000 — EST. HRS. PER YEAR: 300

DELIVERY			NON-ACCEPTABLE LOTS		
CONTINUOUS [X]	INTERMITTENT [ ]	IRREGULAR [ ]	DETAILED [ ]	REJECTED [X]	EITHER [ ]

OLD SAMPLING SCHEME

USUAL LOT SIZE: 2500 — SAMPLE SIZE: 100 — A.O.Q.L.: 1.5 % — PROCESS AVERAGE: .709 %

REMARKS: Reissued to place in proper process average class.

NOTES BY STATISTICAL DEPT.

CHECKED BY: X

DATE: X

Fig. 2

1.4 *Records*

This section contains a description of the running records and clerical operations which are used for supervisory control. The records are "Lot by Lot Record of Statistical Sampling Inspection", and "Summary of Results of Inspection", shown in Figs. 3 and 4, respectively.

MD 870-H (5-39)

LOT BY LOT RECORD OF STATISTICAL SAMPLING INSPECTION LAYOUT X

INSPECTION SECTION X

MATERIAL INSPECTED LAMPS

INSPECTION OPERATIONS GAGE FOR OVERALL LENGTH AND DISTANCE FROM END OF TERMINAL TO END OF BULB.

OPERATING DEPT. OPERATIONS ASSEM. OPER. DEPT. NO. X

AOQL 1.5 %

SUMMARY PERIOD WEEKLY

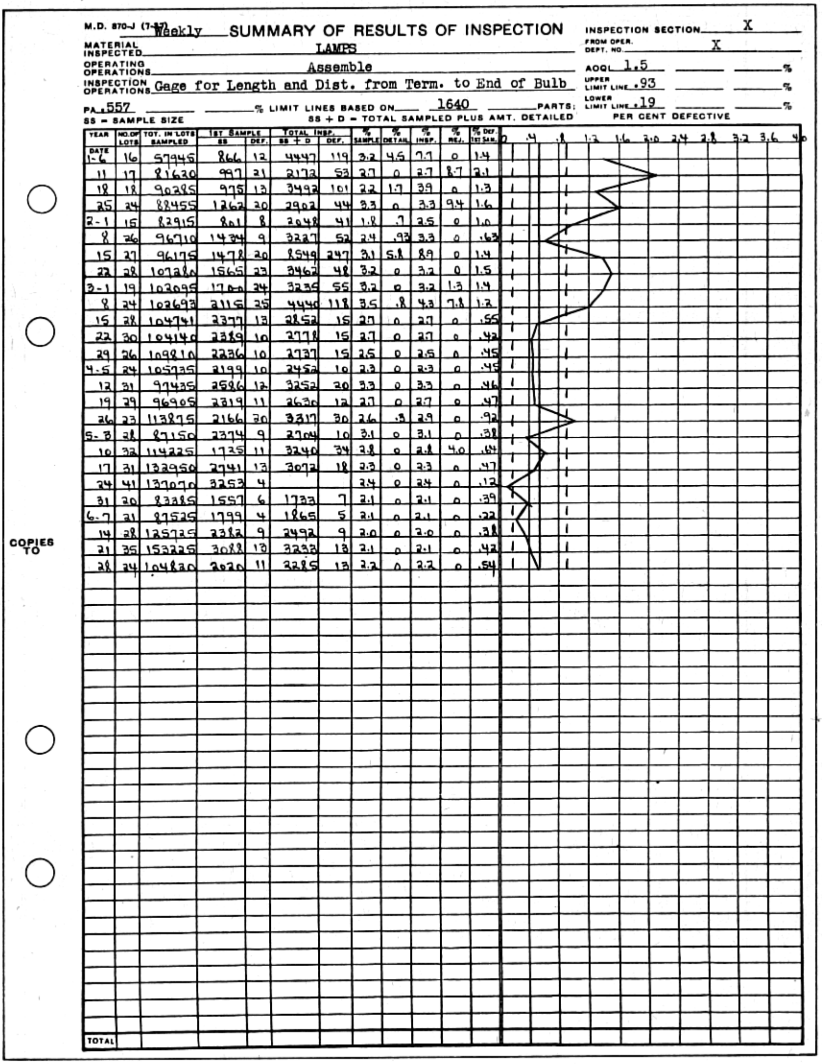
LIST OF DEFECTS IN 1ST SAMPLE (DEFECT: NO. / CHGE. / CLASS)

	1941 YEAR			1ST SAMPLE		2ND SAMPLE		TOTAL DETAILED		LIST OF DEFECTS IN 1ST SAMPLE						
	DATE	CODE OR P. NO.	LOT SIZE	SS	DEF.	TOTAL	DEF.	PARTS	DEF.	LENGTH UNDERSIZE	LENGTH OVERSIZE	BULB UNDER MIN.	OPERATOR OR GROUP NUMBER	INSPECTOR'S CLOCK NO.	DISPOSITION OF LOT PASS. REJECT. ETC.	REMARK NUMBER
1	5-5	C-2	4615	55	1	175	3					1		7	P	
2	"	2-F	1750	49	0										P	
3	"	E-1	1425	49	0										P	
4	"	2-Y	4440	55	0										P	
5	"	2-F	1975	49	0										P	
6	5-6	E-1	2225	55	1	165	4				1				P	
7	"	C-2	3590	55	0										P	
8	"	K-1	3280	55	0										P	
9	"	2-U	1275	49	0										P	
10	"	2-Y	7140	60	2	220	2			1		1			P	
11	5-7	2-Y	11865	60	0										P	
12	"	E-1	2250	55	0										P	
13	"	K-1	2110	55	0										P	
14	"	2-F	1400	49	0										P	
15	5-8	2-Y	5400	55	1	215	3			1					P	
16	"	K-1	2340	55	0										P	
17	"	E-1	5860	60	0										P	
18	"	2-U	7155	60	1	220	2					1			P	
19	"	2-Y	900	47	0										P	
20	5-9	K-1	1740	49	0										P	
21	"	2-Y	2845	55	0										P	
22	"	E-1	5645	60	0										P	
23	"	B-2	3495	55	0										P	(1)
24	"	2-U	4575	55	2	175	5			2					R P 5-10	
25	"	2-F	1160	49	0										P	
26	"	2-U	1000	47	0										P	
27	5-10	E-1	6695	60	0										P	
28	"	2-F	1525	49	1	130	1				1				P	
29	"	B-2	4020	55	0										P	
30	"	2-U	6340	60	1	215	3					1			P	
31	"	K-1	2915	55	0										P	
32	"	2-Y	1275	49	0										P	
33	"	2-U	4575	55	0										P	(1)
34	TOTAL		114225	1725	10	2789	23			4	2	4				
35																
36																
37																
38	REMARKS:															
39	(1) LOT REJECTED—SUBMITTED FOR REINSPECTION AFTER REPAIR															
40																

Fig. 3

The Lot by Lot Record of Statistical Sampling Inspection—Fig. 3

On this form the inspector records the results of his inspection at the time of his observation. An examination of Fig. 3 will indicate how the form is filled out.



M.D. 870-J (7-37) Weekly SUMMARY OF RESULTS OF INSPECTION

INSPECTION SECTION X

MATERIAL INSPECTED LAMPS

FROM OPER. DEPT. NO. X

OPERATING OPERATIONS Assemble

AOQL 1.5 %

INSPECTION OPERATIONS Gage for Length and Dist. from Term. to End of Bulb

UPPER LIMIT LINE .93 %

PA .557 % LIMIT LINES BASED ON 1640 PARTS;

LOWER LIMIT LINE .19 %

SS = SAMPLE SIZE

SS + D = TOTAL SAMPLED PLUS AMT. DETAILED

PER CENT DEFECTIVE

YEAR / DATE	NO. OF LOTS	TOT. IN LOTS SAMPLED	1ST SAMPLE SS	1ST SAMPLE DEF.	TOTAL INSP. SS + D	TOTAL INSP. DEF.	% SAMPLE	% DETAIL	% INSP.	% REJ.	% DEF. 1ST SAM.
1-6	16	57945	866	12	4447	119	3.2	4.5	7.7	0	1.4
11	17	81630	997	21	2172	53	2.7	0	2.7	8.7	2.1
18	18	90285	975	13	3492	101	2.2	1.7	3.9	0	1.3
25	24	88455	1262	20	2902	44	3.3	0	3.3	9.4	1.6
2-1	15	82915	801	8	2048	41	1.8	.7	2.5	0	1.0
8	26	96710	1434	9	3227	52	2.4	.93	3.3	0	.63
15	27	96175	1478	20	8549	247	3.1	5.8	8.9	0	1.4
22	28	107280	1565	23	3462	48	3.2	0	3.2	0	1.5
3-1	19	102095	1700	24	3235	55	3.2	0	3.2	1.3	1.4
8	24	102693	2115	25	4440	118	3.5	.8	4.3	7.8	1.2
15	28	104741	2377	13	2852	15	2.7	0	2.7	0	.55
22	30	104140	2389	10	2778	15	2.7	0	2.7	0	.42
29	26	109810	2236	10	2737	15	2.5	0	2.5	0	.45
4-5	24	105735	2199	10	2452	10	2.3	0	2.3	0	.45
12	31	97435	2586	12	3252	20	3.3	0	3.3	0	.46
19	29	96905	2319	11	2630	12	2.7	0	2.7	0	.47
26	23	113875	2166	20	3317	30	2.6	.3	2.9	0	.92
5-3	28	87150	2374	9	2704	10	3.1	0	3.1	0	.38
10	32	114225	1725	11	3240	34	2.8	0	2.8	4.0	.64
17	31	132950	2741	13	3072	18	2.3	0	2.3	0	.47
24	41	137070	3253	4			2.4	0	2.4	0	.12
31	20	83385	1557	6	1733	7	2.1	0	2.1	0	.39
6-7	21	87525	1799	4	1865	5	2.1	0	2.1	0	.22
14	28	125725	2382	9	2492	9	2.0	0	2.0	0	.38
21	35	153225	3088	13	3233	13	2.1	0	2.1	0	.42
28	24	104830	2020	11	3285	13	2.2	0	2.2	0	.54
TOTAL											

COPIES TO

Fig. 4

The Summary of Results of Inspection—Fig. 4

This form is kept with the inspection layout and the Lot by Lot Records. Entries are made as indicated on Fig. 4. Clerical operations involved in making the necessary computations are explained in the following paragraphs.

1.41 *PA (Process Average)*

The Process Average should be computed at least once every six months, and more frequently when conditions warrant. Only data accumulated since the last computation should be used. When it is known that the quality of the product has changed significantly during the period, use only the data collected since the change.

Record the results of all process average computations and the periods covered by them in the space provided on the sampling layout.

1.42 *Periodic Totaling of Lot by Lot Record and Posting on Summary of Results Form, Fig. 4*

The following columns on the Lot by Lot Record should be totaled at intervals, and may, for contrast, be marked in red:

No. of Lots	*Lot Size*	*1st Sample SS*	*1st Sample Def.*	*2nd Sample Total*	*List of Defects in 1st Sample Total by Columns*
X	X	X	X	X	XXXX etc.

Totals after approximately 20 entries are generally considered satisfactory. The required totals are then posted to the Summary Form, Fig. 4.

1.43 *Per Cent Defective*

The purpose of this figure is to show the average quality of the product as received by the inspector during the period covered and is obtained by dividing the total number of defectives found in first samples by the total number of articles inspected in first samples, and multiplying by 100. Only the results of the first samples are used, in order to accord equitable treatment to all lots.

1.44 *Control Chart*

The per cent defective is plotted on the graph at the right of the summary form (Fig. 4). Control Limit Lines are drawn around the process average to indicate the variation that may be expected due to random sampling. These control limits are determined by the following formulae[3]:

$$\left.\begin{array}{l}\text{Upper Control Limit}\\ \text{for fraction defective}\end{array}\right\} = \bar{p} + 2\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}}$$

$$\left.\begin{array}{l}\text{Lower Control Limit}^{4}\\ \text{for fraction defective}\end{array}\right\} = \bar{p} - 2\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}}$$

[3] The considerations involved in the establishment of control chart limits are discussed in ASA Standards Z1.1–1941 and Z1.2–1941, "Guide for Quality Control and Control Chart Method of Analyzing Data". In this case, 2-sigma limits have been chosen. For this particular application within the manufacturing plant over a period of years, this choice has appeared to strike an economic balance with respect to the net consequences of two kinds of "errors" that may occur in practice; namely, looking for trouble that does not exist and not looking for trouble that does exist.

[4] If this result is negative, the lower control limit is to be taken as zero.

Where $\bar{p}$ = Process average fraction defective

n = Average number of articles in first samples inspected during the summary period.

For example, the records for a typical period of 10 weeks might show the following:

Total number of articles inspected in first samples = 16,400

Process average fraction defective = $\bar{p}$ = .00557 or .56%

Thus, $n = \frac{16{,}400}{10} = 1640$ articles

Hence:

$$\text{Upper Control Limit} = .00557 + 2\sqrt{\frac{.00557\ (1 - .00557)}{1640}}$$

$$\text{“ \quad “ \quad “} = .00557 + .00368$$

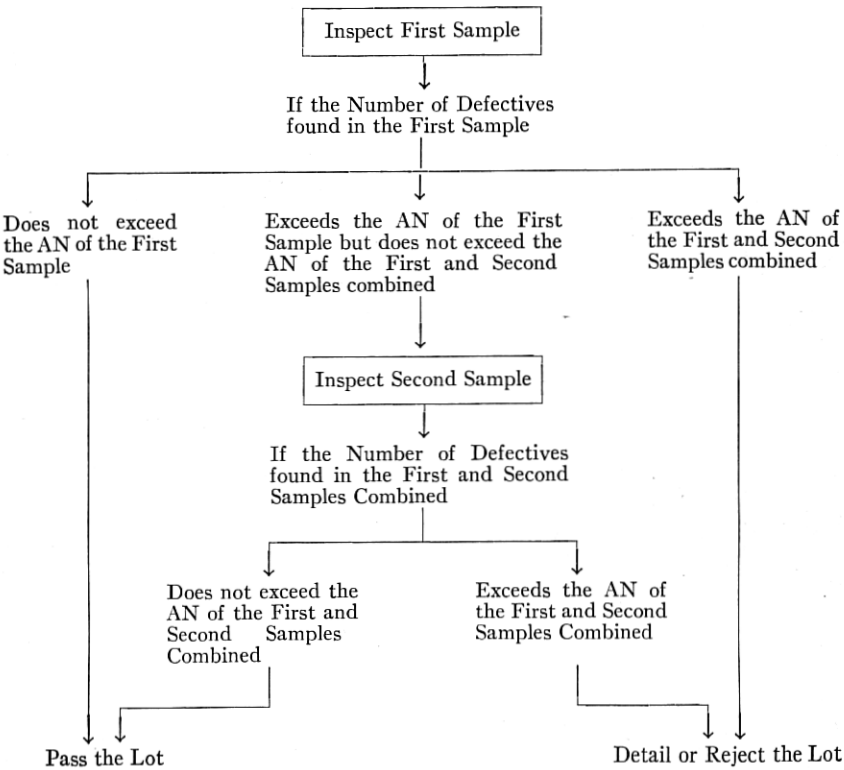
$$\text{“ \quad “ \quad “} = .00925 = .93\%$$

$$\text{Lower Control Limit} = .00557 - .00368$$

$$\text{“ \quad “ \quad “} = .00189 = .19\%$$

2. Application of the Double Sampling Plan by the Inspector

The following flow chart illustrates in sequence the basic steps involved in the inspection of a lot.



An example of the operation of this chart is shown below:

Example:
AOQL = 1.5%
Process Average = .56%
Lot Size = 4615

On consulting the sampling table on the layout, which is information obtained from the table for AOQL = 1.5%, Process Average Column .31–.60% (see Fig. 1), it will be found that for a lot of 4001–5000 parts the following sample sizes (SS) and allowable numbers of defectives (AN) are shown:

Lot Size	*First Sample*		*Total Sample*		
	SS	*AN*	*Add.*	*Total*	*AN*
4001–5000	55	0	120	175	4

This means that for the first sample 55 parts should be selected and completely inspected for all items covered by the Sampling Layout. In order that the per cent defective may be accurately determined for control purposes, a *complete inspection* of the first sample must be made regardless of how defective it may be. If five or more defectives are found in the sample of 55 parts, the lot should be rejected or detail inspected, or otherwise disposed of as shown on the layout.

If no defectives are found in the 55 parts, the lot should be passed.

If one, two, three, or four defectives are found in the 55 parts, the second sample of 120 additional parts should be selected.

In the combined sample of 175 parts, a total of four defectives is allowed. if a total of five defectives is found before all of the 175 parts are inspected, sampling should be discontinued and the lot disposed of as indicated on the layout.

If less than five defectives are found in the combined sample of 175 parts, the lot should be passed.

2.1 *Counting the Lot Size*

The determination of the lot size may be made by weighing methods or careful estimates. It has been found in practice that an estimate which is within 20% of the true value of lot size is satisfactory for sampling purposes.

2.2 *Counting the Sample Size*

Since the relation between corresponding Lot Sizes and Sample Sizes for a particular AOQL is not linear the same order of accuracy of count does not prevail. If, in using a given sampling table, a sample smaller than that prescribed is taken, the result is to increase the AOQL, and if a sample larger than that prescribed is taken, the result is to decrease the AOQL and increase the cost of inspection.

Counting becomes a simple matter when articles are handled in compartment boxes or when the gage or testing device provides for automatic count Regardless of what method of counting is used there should be agreement between the size of sample selected and sample size indicated in the sampling table.

2.3 *Reinspection of Rejected Lots*

In order to guarantee the protection promised by a particular Double Sampling Plan it is required that a rejected lot be completely cleared of all defects. The rejected material should be repaired and returned for reinspection as one lot. It should then be reinspected for all inspection items using the sample size that would normally apply to a new lot of the same size. If a defect is found during reinspection it is evident that proper repair or sorting has not been accomplished. Such a lot should, of course. not be considered acceptable until all defects are removed.

In the Lot-by-Lot Record, the results of resampling of rejected lots are recorded on a separate line and the entry circled or otherwise identified so that it will not be included with the results of first samples on the Summary Form.

3. Supervision of the Double Sampling Plan

In order that maximum advantage may be gained from the use of Double Sampling Lot Inspection it is necessary that attention be given to the topics listed below. Upon proper attention to these factors depends the effectiveness of the Plan.

3.1 *Changes in AOQL*

There is no assurance that the value originally selected for an AOQL will continue to be the most satisfactory in view of changing factors relating to the product, such as:

3.11 Changes in design of the product or changes in the requirements for inspection items may increase or decrease the trouble caused by the acceptance of defective parts and therefore will occasion a review of the AOQL value.

3.12 New methods of manufacture that change the difficulty and therefore the cost of making a product will necessitate a reconsideration of the AOQL value.

3.13 An excessive number of complaints or other reports of difficulty from succeeding stages of manufacture or from customers may indicate too large an AOQL.

3.14 If no significant changes such as those mentioned above exist and there are repeated lot rejections, it would appear that quality is unsatisfactory. However, it should be determined whether or not succeeding operations can possibly tolerate more defectives than they are actually receiving and, if this is the case, the AOQL may profitably be increased.

3.2 *Changes in Process Average*

The economy of the sampling plan tends to decrease when the level of quality of the product shifts outside the range of process average on which the layout was based. The sampling table on the layout should ordinarily be changed whenever the process average shifts from one range to another. However, before reissuing the layout, the reason for the shift should be determined. If the process average has been reduced, an attempt should be made to make the change permanent; or if it has been increased, the cause should be eliminated.

3.3 *Interpretation of the Control Chart on "Summary of Results of Inspection" Form*

It is very important to review the Control Chart of per cent defective (Fig. 4) frequently as it is an index of the success of the sampling plan. Not all fluctuations of the per cent defective are significant. Even though the quality of the product is controlled, the results of sampling inspection may produce fluctuations in the indicated per cent defective. These variations are measured by a simple control chart on the "Summary" form which employs control limits for values of per cent defective. As long as the plotted points of the per cent defective remain within control limits the fluctuations are no greater than may reasonably be expected from a uniform manufacturing process. However, if a point goes above the upper control limit, the cause may be defective workmanship, defective raw materials, or even a change in the severity of inspection. If a point goes below the lower control limit, the cause may be an improvement in quality or a change in the definition of a defect through misinterpretation or changes in inspection equipment or method of check. If the curve of the plotted points hugs either limit line or shows a definite trend toward one side or the other, a significant change in the quality of the product is indicated.

In order to achieve control of the quality of a manufactured product, direct and immediate action must be taken in order to stem unfavorable trends. The presence or absence of a satisfactory quality level may be detected by means of inspection, but such a level can only be originated and maintained by adequate manufacturing methods and equipment in the hands of a quality-minded producing personnel.

3.4 *Changes in the Definition of a Defect*

Either laxity or severity of inspection may cause the "reported" per cent defective to show significant changes even though the actual per cent defective is unchanged. This may result from a change in the definition of a defect; that is, the same condition may at times be considered defective and at other times acceptable. This happens most frequently in border-line cases. To avoid such variations it is necessary that the condition that constitutes a defect be clearly defined and strictly followed in all inspections.

3.5 *The Abnormal Existence of One Kind of Defect*

When the sampling scheme includes the inspection for several different requirements, the Allowable Number may at times be exceeded because of one kind of defect only. In other words, the lot would be satisfactory if this one kind of defect did not exist. If the same defect persists for several lots, it should receive definite supervisory attention. If substantial improvement is not feasible, it may be convenient to remove the inspection item to a separate sampling layout.

3.6 *Abnormal Distribution of Defectives*

Occasionally there may be reason to believe that a group of parts submitted for inspection is not uniform in quality throughout, that is, not a true lot as defined in the early part of the paper. Such a group should be divided into homogeneous sections and each section sampled separately. However, when this happens, subsequent lots for sampling purposes should be similarly subdivided, that is, they should be confined to the output of one source at a time; for example, one machine, one operator, or one batch of material, etc., based on one system of causes, so that control of quality at each source may be applied, and the consumer protected from receiving spotty product.

In addition to the specific steps followed in establishing and operating a sampling plan it must always be remembered that, since relatively important decisions concerning the acceptance of product hinge upon the results of an examination of a small group of parts, inspection must be conscientious and accurate. In order to guarantee the order of protection promised by the sampling plan, the results of inspection and the prescribed procedure for disposing of individual lots must be regarded with thorough respect.