so it is possible to specify an AOQL. When an AOQL is specified for a particular product, we try to select a sampling plan whose AOQL is equal to the specified value.

To make it easier to select plans on this basis, Dodge and Romig have published tables of sampling plans classified according to their AOQL's. See Reference No. 11. The values of AOQL range from 0.1% to 10% defective.

The plans in these tables are arranged in such a way that, if the engineer selects a plan under the correct "process average," he will minimize the total number of pieces which must be looked at, including both sampling and 100% inspection. Values of "p_t%" (lot tolerance percent defective) are included as supplementary information.

These tables are useful wherever we are chiefly interested in setting a fixed maximum limit on outgoing quality and are willing to achieve this by a combination of sampling and 100% inspection. Both of the sampling plans shown in Figure 238 can be found in the Dodge-Romig AOQL Tables.

A typical AOQL sampling table is shown in Figure 240. The caption gives a general idea of how the table is used. For further information see Reference No. 11.

B-4.6 Precautions to be taken in using AOQL sampling plans

Every sampling plan can be classified in all three of the ways described above. The same sampling plan might be called a "1% AQL sampling plan," an "8% LTPD sampling plan" and (if all lots which fail to meet the acceptance number of the plan are inspected 100%) a "2.5% AOQL" sampling plan. Many of the sampling plans used at Western Electric are selected on the basis of AOQL rather than on the basis of AQL or LTPD.

Since AOQL plans involve a combination of sampling and 100% inspection, these plans are often subject to misinterpretation and misuse. Engineers and inspection supervisors should guard against the following errors.

(1) We sometimes hear of "AOQL sampling plans" being used in connection with destructive tests, or in Receiving Inspection where the rejected lots are junked, returned to the supplier or accepted on an outside limit basis, but where there is no intention whatever of doing 100% inspection on the lots which fail to meet the acceptance number of the plans. It should always be remembered that unless the prescribed 100% inspection is done, we will not get the protection promised by an AOQL sampling plan.

(2) If the product contains defects to begin with, an AOQL sampling plan will depend on the presence of the rejected lots, which have been made perfect by screening, to dilute the percentage of defectives which may still be present in the lots accepted. People using AOQL sampling plans sometimes make the mistake of sending the accepted lots to one customer (or user) and the rejected lots to another. The first customer may get highly defective product. Also, if the accepted lots are sent to the storeroom during the time when the rejected lots are being sorted and repaired, the product in the storeroom during that time may be much worse than the AOQL. The same thing may be true of accepted lots which are sent to the next Operating department to be assembled while the rejected lots are being gone over. Until the rejected lots catch up with the accepted lots and can be considered in combination with them, there is no guarantee that the product will be meeting the AOQL.

B-4.7 What the Operating organization should know about AOQL sampling plans

Operating people often assume that a "2% AOQL sampling plan" will accept product which is 2% defective. That is, if Inspection is using a 2% AOQL plan, and if Operating submits product which is actually 2% defective, they feel that all or most of the submitted product should pass the inspection plan. Engineers also frequently make this assumption in discussing suitable quality levels for sampling or in agreeing to the use of some specific proposed plan. However, unless the AOQL sampling plan is deliberately chosen with this in mind, a 2% plan may reject large portions of 2% defective product. The following example will show why it is necessary to restrict the choice of plans.

Suppose a sampling plan were to be chosen solely for its AOQL. The following plans will have an AOQL of 2% when used for lots of approximately 1000.

(a) $n = 18, c = 0$

(b) $n = 40, c = 1$

(c) $n = 65, c = 2$

(d) $n = 90, c = 3$

While all of these plans have a 2% AOQL, they will reject very different amounts of 2% defective product.

2% AOQL Sampling Plans	*Approximate Percentage of Product Rejected (if product is running at 2% defective)*
(a) $n = 18, c = 0$	30%
(b) $n = 40, c = 1$	19%
(c) $n = 65, c = 2$	14%
(d) $n = 90, c = 3$	11%

In all four cases the amount of product rejected is quite large. If the Operating department wishes to avoid these rejections, it will have to maintain a quality level considerably better than 2%.

To find how good the product must be in order to avoid rejection, proceed as follows:

(1) Plot the OC curve of the sampling plan in question.

(2) Find the point where the curve drops away from the 1.00 probability of acceptance.

(3) The corresponding percent defective is the point at which Operating must aim if it wishes to have its product accepted regularly by Inspection.

The following are the points at which Operating should aim in the case of the plans shown above.

2% AOQL Sampling Plans	*Necessary Level of Quality to assure regular acceptance (where "regular acceptance" means acceptance about 98% of the time)*
(a) $n = 18, c = 0$	0.1% defective
(b) $n = 40, c = 1$	0.5% defective
(c) $n = 65, c = 2$	0.9% defective
(d) $n = 90, c = 3$	1.1% defective

Both Operating and Engineering need to know this "target value" whenever Inspection is using AOQL sampling plans.

All four of the above plans are taken from the Dodge-Romig 2% AOQL Single Sampling Table. Plan (d) is the one recommended in the Table for product which is running 2% defective.

To guard against excessive rejections like those shown above, avoid choosing AOQL sampling plans from the incorrect column for "process average." Plot the OC curve for each sampling plan chosen, and determine a suitable target value for Operating as indicated above. If the target value is not one which can be met economically, it may be necessary to revise the choice of AOQL.

B-5 SAMPLING PLANS FOR CONTINUOUS PROCESSES

Sampling plans may be divided into three principal types.

(1) Plans for continuous processes.

(2) Plans for lot-by-lot inspection.

(3) Special plans which involve, in a sense, lot-by-lot inspection but which are applied to a series of lots considered as a group.

The plans to be considered in this Sub-section are of the continuous type.

Continuous process sampling plans are used for production processes where no separate "lots" exist. They are generally used on conveyors but are applicable to any continuously-running operation where we do not wish to accumulate the product into lots for purposes of inspection. All of the continuous sampling plans which are available at present are of the AOQL type.

B-5.1 General idea of continuous sampling

Suppose we have a continuous flow of product which is 4% defective. We begin to inspect this product, classifying each unit in order as defective or non-defective. If O represents a non-defective unit and X a defective one, the record of inspection results would be similar to the following:

OOOOX OOOOOOOOX OX OOOOOOOOOO

OOOOOOOOOOOX OOOOOOOOOOOOOOO

OOOOOOOOOX OOOOOOOOOOOOOO

In lot-by-lot inspection we would count the total number of defectives in a sample from a given lot. In continuous inspection we have no clearly defined lot. Therefore, instead of counting the total number of defectives, we count the number of good units between two successive bad ones. It is possible to set up an acceptance standard for a sampling plan in terms of some required number of successive units which must be found "clear of defects" in order to permit the product to be accepted.

The number which must be found clear of defects is called the "clearing sample," i.

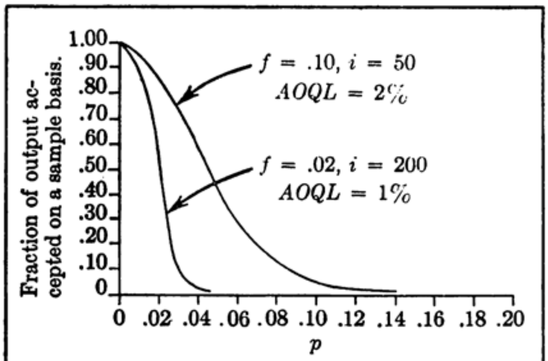


Fig. 241. OC curves for continuous sampling plans CSP-1.

B-5.2 Operation of the continuous sampling plan CSP-1

The operation of a continuous sampling plan is shown on page 257.

This sampling plan is known as "CSP-1." It calls for clearing when a single defect is found. Other continuous sampling plans (CSP-2 and CSP-3) do not call for clearing on the occurrence of a single defect during sampling, provided no further defect is found in a specified number of units thereafter. Details of these plans can be found in Reference No. 8.

In continuous sampling there is no fixed sample size, "n." Instead, the inspector selects a specified fraction of the product, "f." He uses a clearing sample, "i," to determine whether it is satisfactory to ship the product without clearing. The two values "f" and "i" determine the characteristics of the plan and are used in calculating its OC curve. The OC curve shows the percentage of total production that will be accepted on a sampling basis.

Figure 241 shows OC curves for two continuous sampling plans which have AOQL's of 1% and 2% respectively. The 2% plan may be compared with other 2% AOQL plans—for example, C and E on page 243.

The curves on page 258 are used (in place of sampling tables) to select continuous sampling plans CSP-1. Select the curve representing the desired AOQL (in percent). Then read "f" in percent on the scale at the left, and "i" in units of product on the scale at the bottom.

B-5.3 Field of application for continuous sampling

Continuous sampling plans are suitable for much wider application than the obviously continuous or conveyorized processes. In modern manufacture most of the operations are essentially continuous in nature, and when product is accumulated into "lots" it is mainly for convenience in inspection, handling and shipment. Wherever the product lots are formed artificially and for convenience, continuous sampling could be employed in place of lot-by-lot sampling.

As in the case of any AOQL sampling plan, protection depends primarily on the sorting or "clearing." Further information on continuous sampling can be found in Reference No. 8.

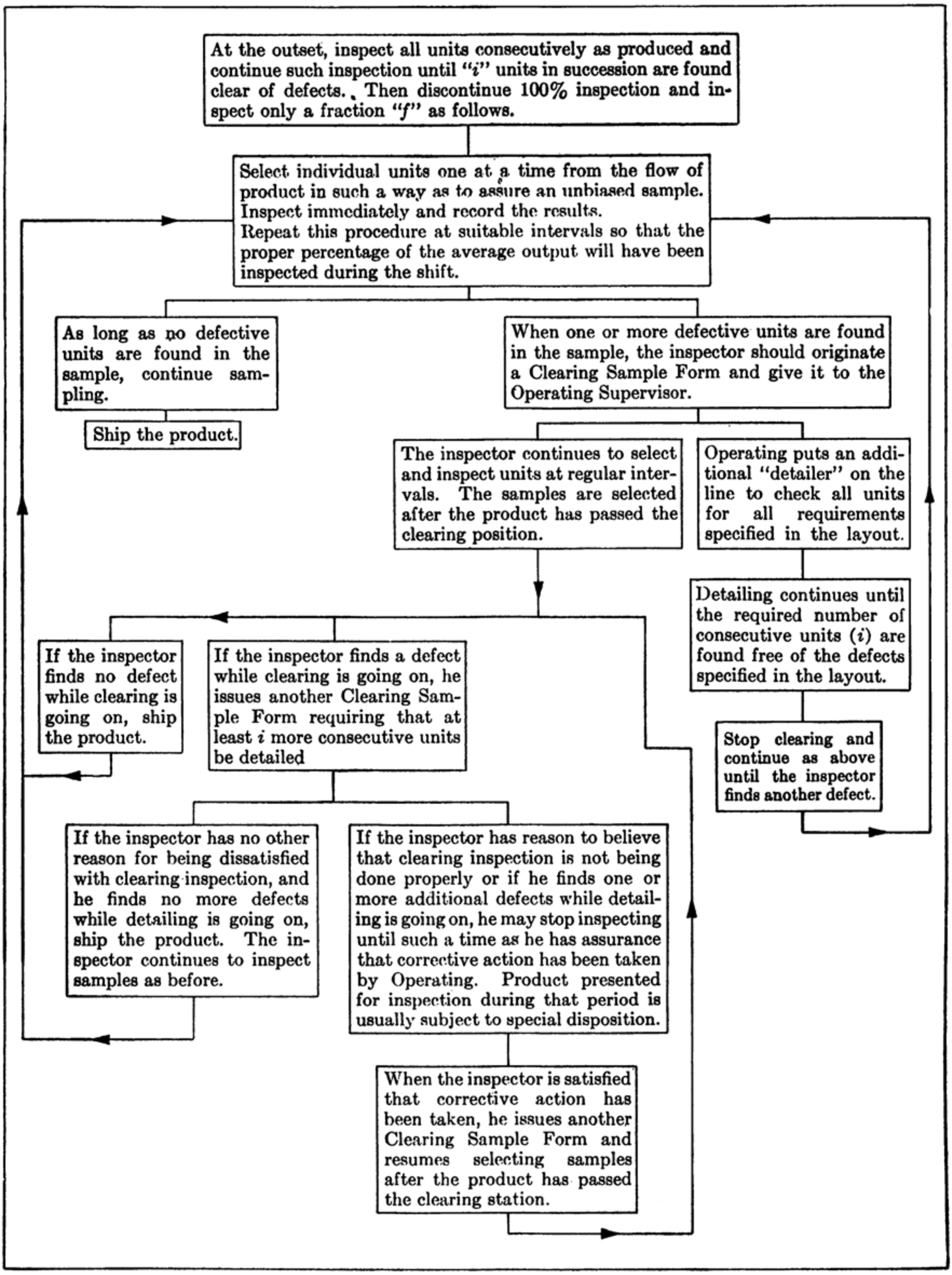


Fig. 242. Operation of a continuous sampling plan: CSP-1.

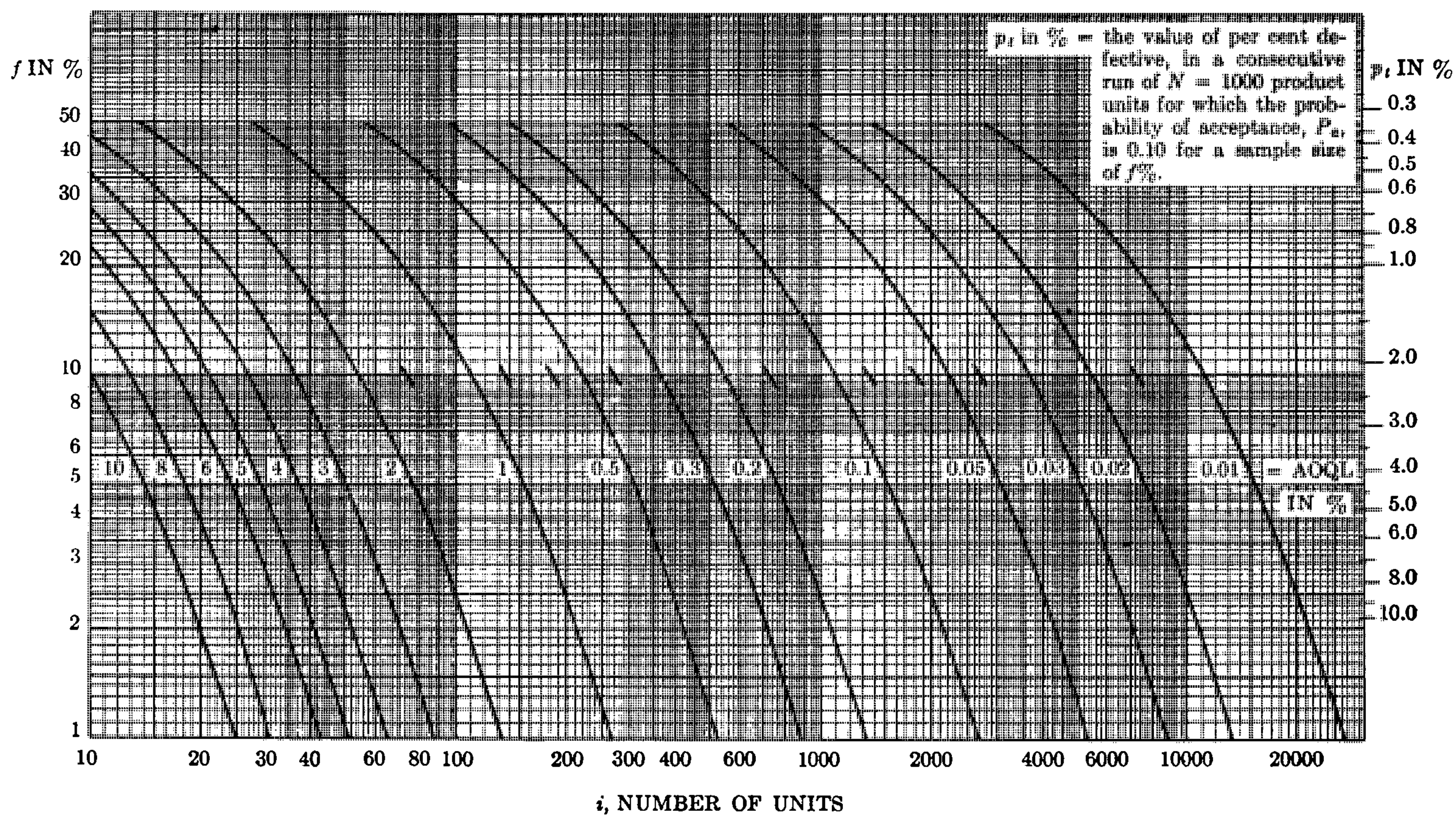


Fig. 243. Curves for selecting continuous sampling plans CSP-1.

B-6 SAMPLING PLANS FOR LOT-BY-LOT INSPECTION

Lot-by-lot sampling plans may be used wherever the product to be inspected can be conveniently accumulated into lots. A "lot" is defined as a collection of similar pieces submitted at one time for inspection. The number of pieces in the lot is called the "lot size." The lot size may be the number specified on the delivery ticket, or it may be simply the number produced in one hour or one shift or some other natural division of time. The "lot" to be used for any specific sampling plan should be clearly stated in the Inspection Layout.

Lot-by-lot plans are called "single sampling" if acceptance or rejection is based on a single sample, and "double" or "multiple sampling" if there is provision under certain circumstances for taking a second or subsequent samples.

The "sample size" in a lot-by-lot inspection plan is the number of parts selected at random from the lot. In lot-by-lot sampling this is always a definite number, never a percentage. The sample size is designated as SS or "n."

The "acceptance number" in a lot-by-lot sampling plan is the maximum number of defective units (or defects) in the sample or samples under consideration that will permit the acceptance of the inspection lot. The acceptance number is designated as AN or "c."

B-6.1 Description of single, double and multiple sampling

Single sampling means that the decision to accept or reject is based on the inspection of a single sample.

Double sampling means that inspection of the first sample leads to a decision to accept, reject or take a second sample. Inspection of a second sample, when required, leads to a decision to accept or reject.

Sequential sampling means that after each unit is inspected, a decision is made to accept, reject or inspect another unit. Inspection is continued as long as may be necessary to reach a decision to accept or reject. In some cases, a sequential plan provides for taking a series of *groups of units*, rather than a series of individual units. This is called "group sequential sampling."

Multiple sampling is a form of group sequential sampling in which the plan is "truncated"; that is, a maximum limit is set on the number of groups which need to be inspected in order to reach a decision to accept or reject.

In all of these plans the inspector is given specific instructions on how to dispose of the product on the basis of the findings in his sample. Diagrams showing the operation of single, double and unit sequential sampling plans are given in Figures 244–246.

A *single sampling plan* gives the inspector one sample size and one acceptance number. If a "rejection number" is stated, it is simply one more than the acceptance number.

Sample	*Acceptance Number*	*Rejection Number*
110	4	5

A *double sampling plan* gives the inspector two sample sizes (n_1 and n_2) and two acceptance numbers (c_1 and c_2). The second acceptance number applies to both samples combined. If a rejection number is stated, it is one more than the acceptance number for the first and second samples combined.

Sample		*Acceptance Number*	*Rejection Number*
n_1	75	2	8
n_2	150	—	—
Combined	225	7	8

A *multiple sampling plan* gives the inspector a series of sample sizes, and for each of these an acceptance number and a rejection number. The inspector takes the first sample and compares his findings with both the acceptance and rejection numbers. If the number of defectives (or defects) is equal to or less than the acceptance number, he accepts. If it is equal to or greater than the rejection number, he rejects. If it falls between the acceptance and rejection numbers, he must inspect another sample. As in the case of double sampling, the acceptance and rejection numbers apply to the combined samples.

Sample		Acceptance Number	Rejection Number
First	30	—	3
Second	30	1	4
Third	30	2	5
Fourth	30	4	6
Fifth	30	5	7
Sixth	30	6	8
Seventh	30	7	8

The "unit sequential" sampling plan shown in Figure 246 is similar to multiple sampling except that each sample consists of one unit.

The advantages of single sampling are:

(1) A constant inspection load (provided rejected lots are sent back to Operating).

(2) Simplicity of administration.

(3) Better control of inspection piece rates.

(4) Low cost of selecting samples.

(5) Smallest amount of record keeping.

The advantages of double sampling are:

(1) Smaller average amount of inspection, particularly when the incoming product is very good or very bad.

(2) A possible psychological advantage associated with the idea of giving the lot a "second chance."

The advantages of sequential sampling are similar to those of double sampling.

Sequential sampling usually requires the smallest average amount of inspection in the long run.

In any comparison of single, double and multiple sampling plans, care should be taken to assure that the plans being compared have similar OC curves. Some of the apparent advantages of a particular plan may be at the cost of less protection for the producer or consumer or both.

B-6.2 Factors to be considered in determining the size of a lot

The choice of lot size is important in determining the economy of a lot-by-lot sampling plan. For a given quality protection the sample will generally be a smaller proportion of the lot as the lot size increases. There is, therefore, a definite advantage in making the lots large. However, the following limitations should be considered in determining the most economical size of lots.

(1) *Physical considerations involved in accumulating, storing, handling and selecting samples from very large lots.* The size of inspection areas, the size and number of storage areas, and the available facilities for handling product between these areas must be considered.

(2) *Disruption of the orderly flow of product caused by accumulation of a large lot.* The product being inspected is usually scheduled for immediate stocking or shipment. Supplies of parts and assemblies may be unduly delayed if we wait for the accumulation of very large lots.

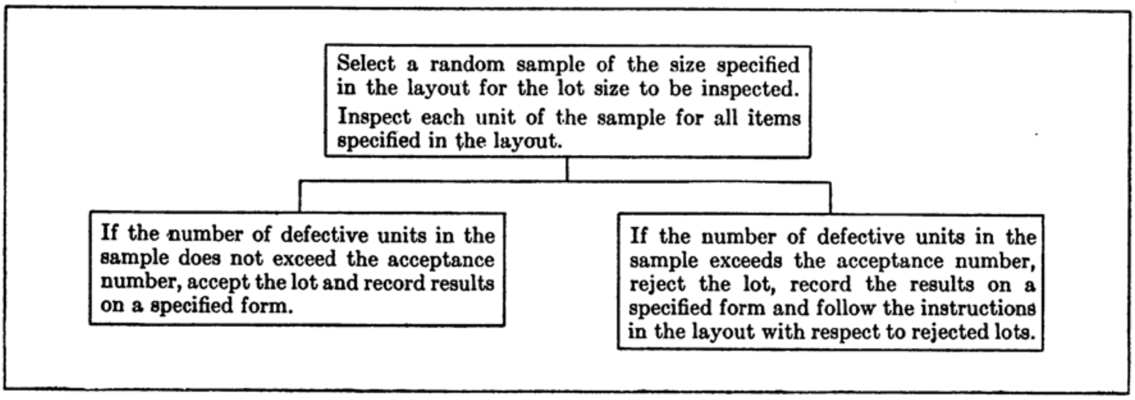


Fig. 244. Lot-by-lot sampling plan (single sampling).

(3) *The effect of mixing product from different cause systems.* Large lots increase the difficulty of selecting a random sample. They also make it difficult or impossible to identify the source of work and tend to prevent the efficient tracing of causes.

(4) *Difficulties encountered when large lots are rejected.* Losses and other difficulties increase when large lots are shipped back to suppliers or have to be held for detailing or rerouted to other departments for repairing or scrapping.

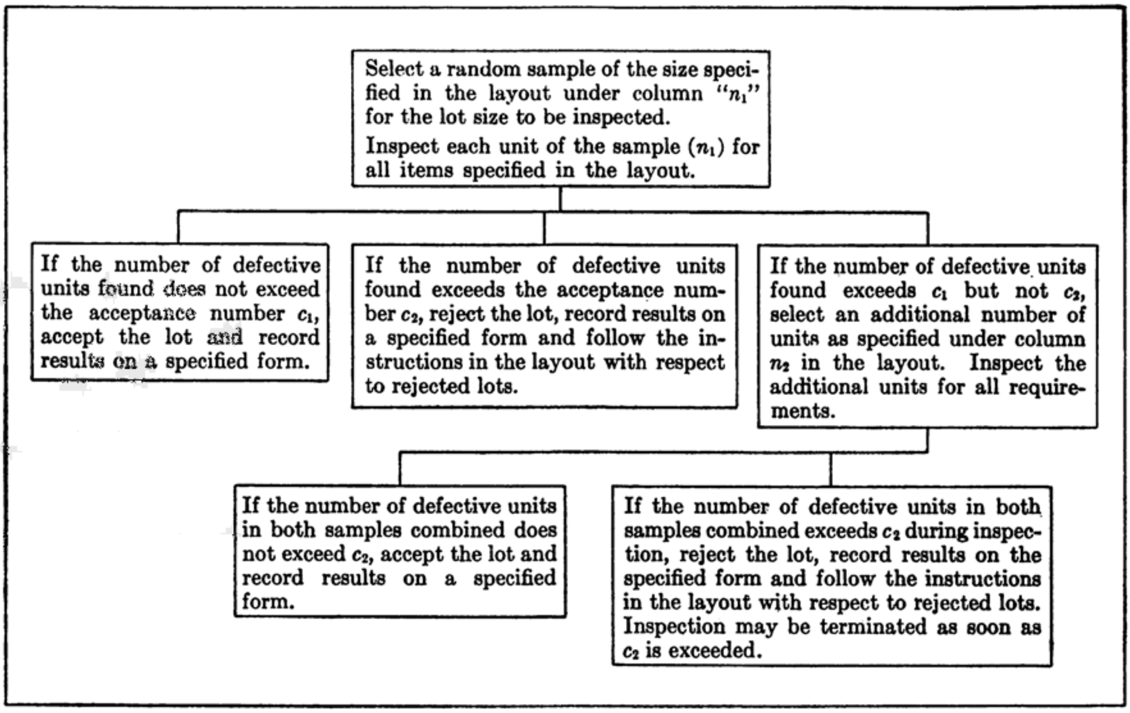


Fig. 245. Lot-by-lot sampling plan (double sampling).

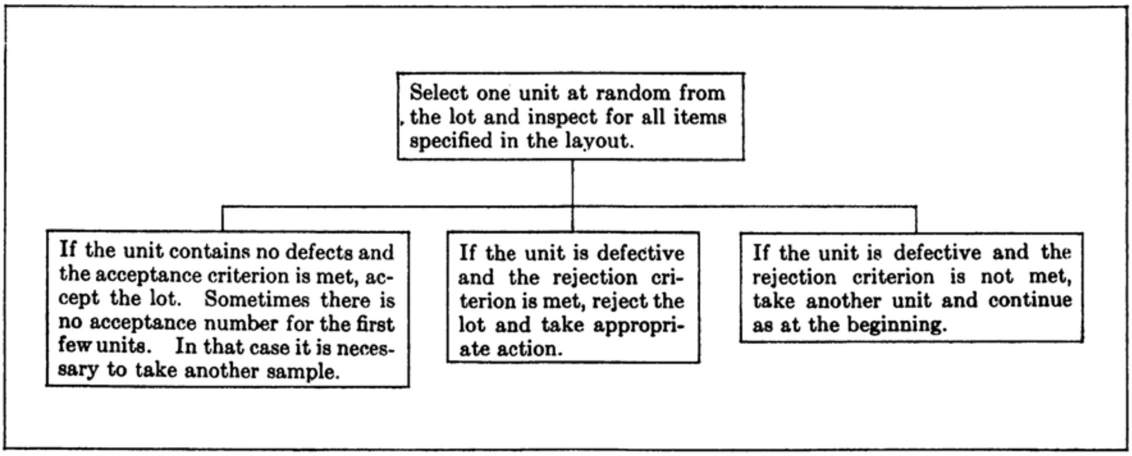


Fig. 246. Lot-by-lot sampling plan (unit sequential sampling).

(5) *Delay in picking up a prompt warning of trouble because of having fewer samples.* The engineer and the shop often rely on the acceptance procedure to give them a warning when something has gone wrong. This can sometimes be as important as the mathematical limitation of defectives which is provided by the plan. The delay we can expect to experience before a warning of trouble is given is directly related to the number of samples taken. The use of large lots and therefore fewer samples tends to increase the delay, with the following bad effects:

During the time of delay more bad product may be made. This can result in new costs, including the cost of disposal or repair, possible shortage of critical materials, and waste of valuable time. One such unnecessary delay could result in such added cost to the job that it would render quite unimportant the calculated saving in the number of pieces inspected.

In order to control the amount of inspection performed in connection with lot-by-lot sampling, the engineer should specify the desired or normal lot size in the manufacturing layout. The inspection layout need then provide only for the usual range of lot sizes that will be submitted for inspection. Where process control is used in the shop, inspection lot sizes should be related to the process control activities. One of the by-products of Operating control charts is that they make it possible for Inspection to obtain more homogeneous and more suitably-sized lots.

B-7 SPECIAL TYPES OF SAMPLING PLANS

While most inspection problems can be handled by using either continuous sampling plans or lot-by-lot sampling plans, as shown in Sub-sections B-5 and B-6, occasionally the need arises for a special type of plan. Among such plans are the following:

Chain sampling plans—Reference No. 10
Skip-lot sampling plans—Reference No. 9
Variables acceptance plans—Reference No. 4
Narrowed limit plans—References No. 34 and 43

Frequently it is found that Inspection can

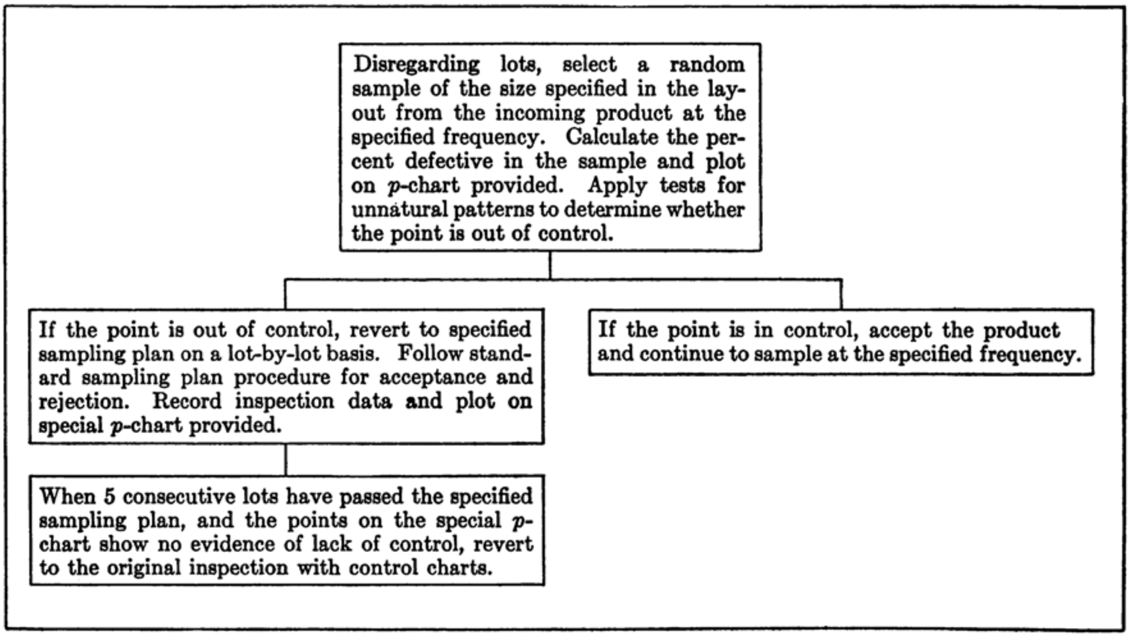


Fig. 247. Control chart sampling plan using *p*-charts.

benefit by using a control chart instead of the more usual type of plan. When control charts are used for acceptance or rejection, rather than for process control, they are known as "control chart sampling plans" rather than as "process control charts." A plan of this type is shown in Figure 247. See also the plans for "Minimum" or "Audit" inspection on page 274.

Any type of chart may be used: $\bar{X}$ and R chart, p-chart, c-chart, chart for individual measurements, etc.

When control charts are used for acceptance purposes, it is necessary to specify

(1) What shall be taken to be evidence of unsatisfactory quality.

(2) What action shall be taken with respect to (a) the product from which the sample was taken, (b) the previous product and (c) the subsequent product.

(3) What shall be used as a criterion for deciding that the chart is back in control.

One commonly used procedure is indicated in Figure 247. In critical cases the engineer may instruct the shop (or the inspector) to do 100% inspection of all product associated with an out-of-control point on the chart.

Note that this is quite different from the use of control charts for process control. In process control it may only be necessary to correct the process with reasonable promptness. It is not usually necessary to sort the product associated with out-of-control samples.

B-8 PROPER GROUPING OF INSPECTION ITEMS

Theoretically, sampling plans should be applied to one characteristic at a time. However, it is permissible to group inspection items for convenience provided certain conditions are met. The principal condition is that it must be possible to treat the group of characteristics as if they were one. Failure to keep this point in mind is responsible for many of the errors made in acceptance sampling.

Grouping a number of items on one sampling plan may simplify the inspector's job and make it faster. Inspection records are also reduced in number, since the inspector is required to keep separate records for each sampling plan used. In Final Inspection it is sometimes possible to use more generous AOQL's for a group of items than if the items were divided into several plans.

Grouping of inspection items, however, requires careful study. The result of each suggested grouping should be carefully examined in the light of its effect on both Inspection and Operating. Inappropriate groupings may result in unnecessary interference with production and may tend to increase Operating and Inspection costs.

In general, avoid grouping together defects with different degrees of seriousness; characteristics that require widely different inspection times; defects that occur frequently with defects that occur very seldom. Remember that sampling plans have to be designed to give protection under the most unfavorable conditions, and this means that they may be forced to reject a certain number of normally acceptable lots. To minimize the cost of screening such lots it is advisable not to include too many items in one group. *Do not include more items in one group than the shop will be able to screen for conveniently when a lot is rejected.*

In handling defects having different degrees of seriousness, first group the defects into two or more classes as follows:

Critical • Major • Minor.

The "demerit" lists issued by Quality Assurance (see page 270 and Reference No. 36) can be used as a guide in judging the seriousness of each defect. Arrange to keep the minor defects separated from the major and critical defects as much as possible.

Avoid grouping troublesome items (most likely to cause rejection) with other items which rarely cause trouble. Lump together items that (a) occur very infrequently or (b) can be readily checked at one time. Inspection piece rates should also be consulted in arranging suitable groups.

B-9 HOW TO SELECT A QUALITY LEVEL FOR SAMPLING

The most difficult decision which an engineer has to make in connection with sampling is the choice of an appropriate quality level. The choice of a suitable level depends on finding the proper balance between quality and cost. Any information which the engineer has on (1) quality requirements, or (2) normal manufacturing operations and costs, will help him to work out this balance satisfactorily.

B-9.1 Quality requirements

Quality requirements are defined, in one way or another, by the organizations or people who are to use the product. Sometimes these requirements are stated very explicitly. Sometimes they are only implied. Those responsible for setting up inspection plans are often forced to estimate the probable needs of the user on the basis of judgment and past experience. The more specifically the needs of the user are defined, the easier it is, in general, to make a decision on the quality level to be used in sampling.

At Western Electric we usually distinguish two different situations:

(a) Final inspection of finished product which is ready to be shipped to an outside customer.

(b) Inspection of sub-assemblies, piece parts and raw materials which are to be used by other departments within Western.

Final Inspection (product to be shipped to customer)

In this case, overall quality requirements have probably been established in the past by Quality Assurance. These standards are expressed numerically, usually in the form of "demerits-per-unit." It is possible for the engineer to obtain the numerical standards from Quality Assurance and convert these directly into appropriate levels to be used in Final Inspection. The details of this are beyond the scope of the present Handbook but full instructions are given in Reference No. 46 (Since this reference contains proprietory information it is available for use only in connection with Company work). These instructions tell how to set up plans for Final Inspection which will meet the "demerit" standards and still provide for maximum economy in inspection. The plans provide for the use of Tight, Normal, Reduced and Minimum inspection levels.

Where demerit standards have not been established for a product, proceed as in the case of piece parts or sub-assemblies.

Sub-assemblies, piece parts and raw materials

For sub-assemblies, piece parts and raw materials the quality requirements are not so clearly defined. The engineer's principal information comes from:

- Complaints from the user (the Assembly Department or other department which must process the material).
- Records of dropouts at subsequent operations.
- The process average (that is, the actual percent defective in the product) during a time when subsequent operations were reasonably free from trouble.

The last point is particularly important. If the process has been delivering product 4% defective for many months without causing trouble, it is not advisable to institute a 1% LTPD sampling plan.

Unless there is a reason for doing otherwise, choose (a) a sampling plan with an OC curve related to the quality regularly produced by the shop in the past (that is, a plan that will accept the normal product practically all of the time); or (b) a plan of the AOQL or LTPD type which is related to the quality which has been accepted in the past by the using organization. For example, if the customer is willing to accept product 3% defective on the average, use a 3% AOQL plan. If the customer is willing to accept product 3% defective only occasionally, use a 3% LTPD plan.

If the engineer knows that there have been quality complaints associated with the product, he may need to tighten the quality standard in order to reduce the complaints. If it is difficult to establish whether there is a real connection between the complaints and the specific requirements to be included in the sampling plan, the engineer should get information on this by making a process capability study.

In general, use tight plans for critical characteristics or characteristics easy to control, and looser plans for others. The demerit lists prepared by Quality Assurance can be used as a guide to the recognized importance of many characteristics.

B-9.2 Cost considerations

The cost considerations which the engineer should keep in mind are the following:

- What is the process average or current level of percent defective?
- Does this process average represent the real capability of the process? That is, is the shop using control charts and are the shop people working with the charts effectively to bring the process into control?
- If the shop has not yet started to use control charts, it may actually be possible to save money by running the process with fewer defectives. In that case the engineer should adopt tentative quality standards for his sampling plans, using his best engineering judgment, and at the same time see that control charts are installed immediately to improve the process average.
- If the shop is using control charts and the process is running near its capability, the engineer should try to set up sampling plans which will accept the normal product. See Paragraph B-4.7. If the OC curve is not carefully chosen, the shop may be harassed with continual rejections even when the process is being run properly.

B-9.3 Conflict between quality requirements and cost considerations

If the engineer finds that the quality requirements are tighter than the normal process capability, he should attempt to resolve this conflict by some economical means. This may include instructing the Operating people to sort all or part of the product prior to sending it to Inspection. However, operational sorting is expensive, and the engineer should make certain that it is really necessary before specifying it in a layout. In most cases the process capability can be improved beyond any previous expectations through the joint efforts of a Quality Control Team.

B-10 FACTORS DETERMINING THE CHOICE OF A PARTICULAR PLAN

The following is a summary of the factors to be considered in choosing an inspection plan.

(1) First consider the number of characteristics to be checked during inspection.

(2) Decide on the way in which these characteristics should be grouped.

(3) For each group, decide on a suitable quality level in terms of percent defective, number of defects per unit or (in the case of variables inspection) the required center or spread of the distribution.

(4) Indicate whether this quality standard is to represent an AQL value (acceptable most of the time), an LTPD value (rejectable most of the time) or an AOQL.

(5) Determine the process capability (or normal process average) for each group.

(6) In lot-by-lot sampling, decide on the most suitable size for the lots.

(7) Consult an appropriate set of sampling tables (or sampling curves) and select a combination of sample size and acceptance number. Immediately obtain or plot the OC curve for the chosen plan.

(8) As far as possible make any necessary adjustments between the process capability and the OC curve of the plan.

(9) In any case where control charts are being used in the shop, consider the possibility of substituting a control chart acceptance procedure as outlined on page 274.

PART C
General Instruction for Inspection

The following is a general instruction for inspectors which will apply to most inspections performed in Western Electric plants. All members of the Inspection Organization, including inspectors and their supervisors, should be familiar with this instruction.

Departures from these procedures are sometimes made necessary by special circumstances. Such departures are usually covered in the individual Inspection Layout.

Instructions for Inspection

1.0 *GENERAL*

1.1 *Purpose*

1.11 The purpose of this instruction is to provide general information on inspection procedures and to supplement the inspection information given in the Manufacturing and Inspection Layouts.

1.12 All inspection should be carried out in accordance with this instruction unless otherwise stated in the Inspection Layout.

1.2 *Definitions*

1.21 Defect
A "defect" is a deviation from a single requirement.

1.22 Defective
A "defective" is a unit of product having one or more defects.

1.23 Lot Size
The lot size is the number of similar parts submitted to Inspection in one group.

1.24 Sample Size
The sample size is the number of parts to be selected at random from the product. In continuous sampling the sample size is expressed as a percentage.

1.25 Acceptance Number
The acceptance number is the maximum number of defective units (or defects) that may be found in a sample without (a) rejecting the product or (b) initiating 100% inspection.

1.26 Clearing Sample
In continuous sampling the clearing sample is the number of successive parts that must be found free of defects before 100% inspection can be discontinued and sampling can be resumed.

1.27 Obvious Defect
An obvious defect is a defect that is immediately apparent and does not require close scrutiny on the part of the inspector.

2.0 *WHEN TO INSPECT*
The points in the sequence of manufacturing operations where inspection should be performed are indicated in the Manufacturing Layout.

3.0 *SELECTION OF SAMPLES*

3.1 *Random Samples*

3.11 Samples should be selected at random from the submitted product.

3.12 In lot-by-lot inspection this means that each unit in the lot should have an equal chance of being selected as the first item in the sample, and after the selection of the first item each remaining unit should have an equal chance of being selected, and so on.

3.13 In continuous sampling, where the units come to the inspector in the order of production, it is assumed that they are already arranged in a random order. The inspector should therefore select individual units (or small groups of units) from the continuous flow of product in such a manner as to assure an unbiased sample.

3.2 *Lot-by-lot Inspection*
Where the product to be inspected consists of a specific number of separate articles or pieces, each sample should be a group of articles taken at random from different locations throughout the lot. The units should be selected without regard to any distinguishable physical differences between the units.

3.3 *Continuous Sampling*
Where the product to be inspected consists of a portion of a continuous flow of product, as on a conveyor, the inspector should select enough units to make up the specified sample by choosing the units one at a time or in small groups from the continuous flow of product. The units should be selected without regard to any distinguishable physical differences between the units, and the intervals between the selection of units should be determined in such a manner as to assure that the sample is unbiased.

3.4 *Control Chart Acceptance Sampling*
Where the product to be inspected consists of the pieces made during the last half hour, the last shift, or some other specified time interval, each sample should be a group of articles taken at random from different locations throughout the quantity of product. The units should be selected without regard to any distinguishable physical differences between the units.

3.5 *Verification Sampling*
Where the product to be inspected is the immediate portion of the output which is being produced at the time when the inspector takes his sample (as in verifying an operator's control chart), each sample should consist of a group of units produced consecutively. The time of selecting the sample should be determined in a random manner in such a way as to assure an unbiased sample.

4.0 *INSPECTION OF SAMPLES*

4.1 *General Procedure*
Each unit of the sample should be inspected for all items listed in the Inspection Layout, using the drawings and the methods or facilities specified. Each unit should also be inspected for obvious defects not specified. See definition of "obvious defect" in Paragraph 1.27.

4.2 *Workmanship Standards*
The degree to which workmanship defects may be present without violating standards of acceptable workmanship should be defined by the product engineer. If necessary, the product engineer should authorize the use of "marginal quality units" to be maintained and stored by the Inspection organization. To obtain such standards the Inspection organization may select units of product considered marginal, acceptable or rejectable, and submit them to the product engineer. The engineer, if he agrees with the quality evaluation, should identify, date and initial the submitted samples. These units may be voided or replaced at any time by the product engineer.

4.3 *Formal Observational Standards*
Formal observational standards are generally furnished where necessary by BTL. The use of such standards should be specified by number on the Inspection Layout. All units of the sample should be compared with these standards.

4.4 *Inspection Records*
The results of inspection should be recorded

on suitable forms as specified in the layout. The following information should be recorded:

1. Lot size (in lot-by-lot inspection.)
2. Sample size.
3. Number and kind of defects.
4. Disposition of lot or product.
5. Identification of part or apparatus.
6. Identification of inspector.

A separate inspection record should be maintained for each sampling plan used, and for each group of items inspected under a common sampling plan. The separate records may appear on the same sheet, provided it is possible to identify them separately.
Records of re-inspection (that is, the inspection of lots re-submitted after they have once been rejected) should be kept separate from the records of initial inspection.

5.0 *ACTION TO BE TAKEN WHEN DEFECTS ARE FOUND*

5.1 *General*
When the acceptance criterion of the sampling plan is exceeded, the inspector should take action as specified in the layout.

5.2 *Obvious Defects*
Obvious defects not listed in the layout should be set aside for repair. They should not, however, be counted against the acceptance number of the sampling plan. For acceptance purposes, only the listed defects should be counted.
If obvious defects not listed in the layout are numerous or appear consistently in the samples, this condition should be called to the attention of the Operating organization and the product engineer.

5.3 *Defective Parts in the Sample*
All defective parts found in the inspector's sample should be plainly marked and should be returned to the Operating organization. The Operating organization should either repair or junk the parts.

5.4 *"Outside Limit" or Non-Conforming Material*
When investigation reveals that rejected material can be used advantageously, the lots should be treated in accordance with standard Manufacturing Instructions. Notification of any special treatment of rejected lots should be forwarded promptly to the Operating organization.

5.5 *Rejected Lots (in lot-by-lot inspection)*

5.51 Rejected lots should be assigned a serial number and recorded on a specified form. The serial number should also appear on the ticket which accompanies the lot when it is returned to the Operating Department.

5.52 The Operating organization receiving the rejected material should sort out all defective units and repair or junk all those parts which fail to meet requirements.

5.6 *Clearing (in continuous sampling)*
When clearing becomes necessary under a continuous sampling plan, the Operating organization is required to sort the product 100% until the specified number of units has been found free of defects. Whenever a defect is found, the sorter should start over in counting the satisfactory units.

5.7 *Reinspection*
Sorted product, when resubmitted for inspection, should be sampled in accordance with the Inspection Layout involved. The sample should be inspected for all requirements specified in the layout. The acceptance number for previously rejected product is usually specified to be zero.

Layouts

In addition to the general instructions given above, all inspection activities should be covered in formal Inspection Layouts. The layout should include:

(1) Identification data describing the product, operation, etc.

(2) Points in the sequence of operations where inspection is to be performed.

(3) Sample size, lot size and acceptance number (or clearing interval).

(4) Method of selecting the sample.

(5) Characteristics to be checked (properly grouped).

(6) Method of measurement or classification.

(7) Information to be recorded or plotted.

(8) Action to be taken.

If certain of these items are covered adequately in the General Instruction, the layout may refer to the General Instruction instead of covering the points in detail.

Quality Assurance

The instructions above do not cover the Quality Assurance continuing independent audit sampling of products and services sold by the Company at the point where they are ready for release to the customer. Quality Assurance appraisals are in terms of demerits. These are compared with certain established standards, also in terms of demerits, in accordance with the demerit system of "quality rating."

Since Quality Assurance is not part of the quality control program, no attempt is made in this Handbook to describe the system of quality audit rating. For information on these procedures see References No. 36 and 46 (Since these two references contain proprietory information their distribution is limited to Bell System personnel, however, a copy of the copyrighted booklet "Quality Assurance in Western Electric" is available from the Company upon request). The former is a complete description from the point of view of Quality Assurance. The latter is a simple explanation from the point of view of Quality Control.

The standards and definitions established by Quality Assurance are often used in planning quality control programs.

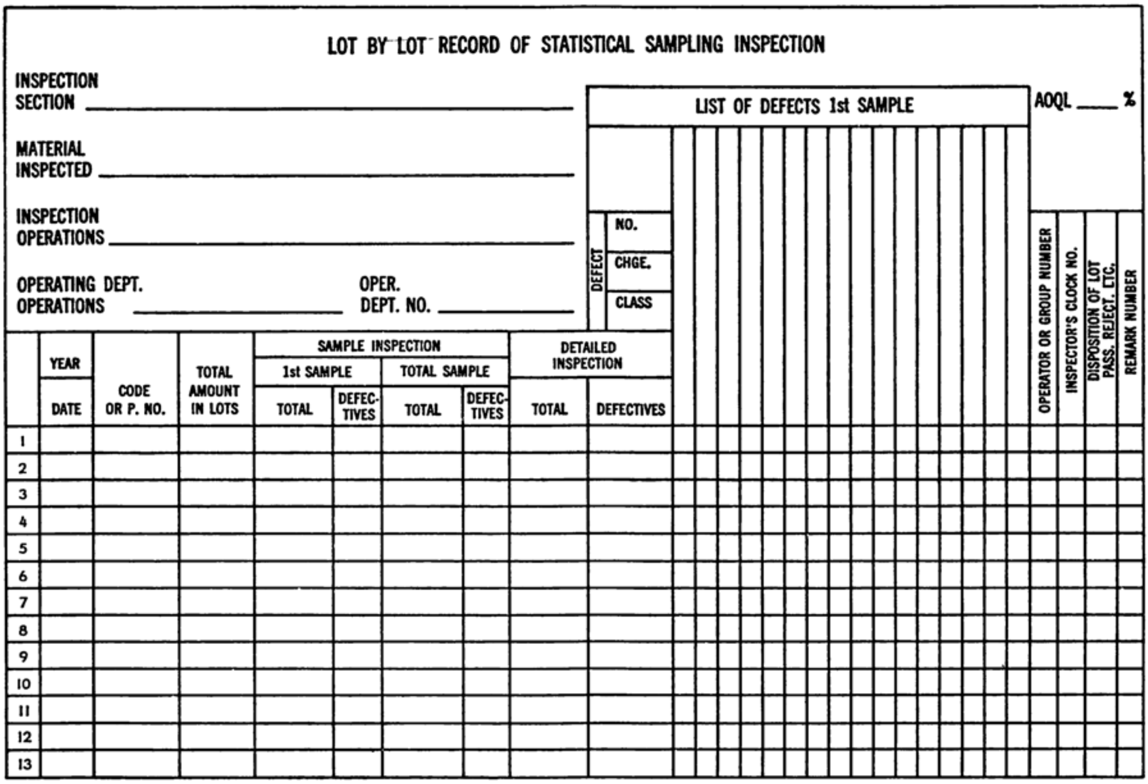
Inspection Dept.	1782 (3)	Inspection Layout No. P-457954-A	
Results Dept.	1721	Issue Date 9/1	
Operating Dept.	1732	Replacing Issue 6/27	
Insp. Control Dept.	5326 (2)	Inspect in accordance with General Instruction No. —.	

Defect Code	Requirement	Equipment
	SAMPLING SCHEME SA2	
	Applies to Groups I and II individually	

Lot Size	SS	AN
1,000- 7,000	42	1
7,001-50,000	70	2

Defect Code	Requirement	Equipment
	Group I	
1	Secure clinching	Visual & by feel
3	Springs to be flat on front insulator (at leading edge)	Visual & .006" feeler
	Group II	
101	Incomplete	Visual
102	Burrs	Visual
103	Cracked insulators and lugs	Visual
105	Slivers	Visual
112	Oil excessive	Visual
113	Foreign material	Visual
114	Bent springs	Visual

Fig. 248. Example of inspection layout: AOQL sampling. The designation "SA2" stands for single sampling AOQL, 2%. SS is the sample size; AN is the acceptance number. The numbers beside the defects refer to a list describing possible defects which is furnished to the inspector.



LOT BY LOT RECORD OF STATISTICAL SAMPLING INSPECTION

INSPECTION SECTION ____________

MATERIAL INSPECTED ____________

INSPECTION OPERATIONS ____________

OPERATING DEPT. OPERATIONS ____________ OPER. DEPT. NO. ____________

LIST OF DEFECTS 1st SAMPLE

AOQL ____ %

DEFECT: NO. / CHGE. / CLASS

	YEAR / DATE	CODE OR P. NO.	TOTAL AMOUNT IN LOTS	SAMPLE INSPECTION 1st SAMPLE TOTAL	DEFECTIVES	SAMPLE INSPECTION TOTAL SAMPLE TOTAL	DEFECTIVES	DETAILED INSPECTION TOTAL	DEFECTIVES	OPERATOR OR GROUP NUMBER	INSPECTOR'S CLOCK NO.	DISPOSITION OF LOT PASS. REJECT. ETC.	REMARK NUMBER
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													

Fig. 249. Form for recording inspection data: Lot-by-lot sampling. In continuous sampling, a form is provided which shows the results on each unit (or group of units) inspected. Colored squares may be used to show the occurrence of defects, the period of "clearing" by Operating, etc.

PART D
Inspection Levels

For most Western Electric products the final quality requirements are necessarily very strict. This results in setting standards for Final Inspection which are often extremely tight. While these tight standards may be necessary in periods of trouble, it should not be necessary to inspect to such severe standards during periods when the process is in a normal state of control. For this reason engineers frequently specify more than one set of sampling plans to be applied to the same product.

The tight plans which may be necessary in emergency are known as Tight Inspection plans. Looser plans to be used in normal periods are called Normal, Reduced and Minimum (or Audit) Inspection plans. In general, the better the process control, the more it is possible to relax the plans for inspection.

The following is one frequently used method of providing for different inspection levels. It applies to a case where the quality standard is expressed in terms of AOQL. It is assumed that AOQL standards have been selected previously as described on page 264.

In the case of finished product, AOQL's may be calculated from the official Quality Assurance quality rates as explained in Reference No. 46.

The engineer begins by selecting a plan for Tight Inspection. From this he derives the other levels in succession, as shown in the following steps:

(1) Tight Inspection

Select a sampling plan whose AOQL is the same as the required quality standard. Call this Tight Inspection (sometimes referred to as Level 1). Here the inspection itself is intended to give complete protection against unsatisfactory quality. There is no reliance on the shop's process control.

A plan of this type usually requires very large samples. Since it has to be designed to give adequate protection in emergency, it may also reject, during normal periods, a considerable quantity of the shop's normal product. To avoid this, set up a second plan as shown in step (2).

(2) Normal Inspection

Select a sampling plan whose AOQL is twice as large as the required ~~quality level.~~ Call this Normal Inspection (sometimes known as Level 2). This inspection is intended to do the following:

(a) Detect a sudden or gradual breakdown in the shop's process control, at which point Inspection should be shifted onto the Tight Inspection basis.
(b) Protect against an unusual deterioration of quality by direct rejection of lots.

Normal Inspection implies a certain amount of knowledge of, or confidence in, the shop's process control. The primary protection, however, remains in the hands of the Inspection department.

While this inspection plan will call for smaller samples than were required in step (1), and will not usually reject a large amount of normal satisfactory product, it may still be possible to reduce inspection further as shown in step (3).

(3) Reduced Inspection

Select a sampling plan whose AOQL is three times as large as the required quality standard. Call this Reduced Inspection (sometimes known as Level 3). This inspection is intended to detect a sudden or gradual breakdown in the shop's process control, at which point inspection should be shifted onto the Tight Inspection basis. It implies a definite degree of confidence in the shop's process control.

Reduced Inspection plans call for very small samples and consequently offer little protection by means of direct rejection of lots. Protection comes primarily from knowledge of shop control. If necessary, inspection can be reduced still further as shown in step (4).

(4) Minimum (or Audit) Inspection

This type of plan may be used wherever process control charts are being used in the shop and where these charts can be expected, under normal circumstances, to show reasonably good control. The inspection is merely an audit, by the inspector, of the shop's own process controls. Under this system, the AOQL is considered unimportant as long as proper control is maintained. Inspection takes only a "verification sample" at specified intervals and plots the result on the chart used by the shop.

This is called Minimum (or Audit) Inspection and is sometimes referred to as Level 4.

As long as the Inspection samples could reasonably be expected to be part of the same statistical pattern shown by the shop, and as long as the shop chart remains in reasonably good control, this indicates that the process is running as it should and that there is no essential conflict between Operating and Inspection findings. The shop chart is therefore used as the basis for accepting product. In event of conflict between Operating and Inspection results, or if the pattern changes and is found to be out of control, Inspection reverts to the Normal or Tight Inspection plans described in step (2) or step (1). Normal or Tight Inspection is continued until the conflict is resolved.

This inspection can be used for single characteristics, groups of characteristics or entire products where it is possible to place reliance on process control. It tends to call for extremely small Inspection samples and at the same time furnishes a high degree of assurance because of the pattern on the control chart. The details of acceptance or rejection for this type of plan are provided specifically in the Inspection Layout.

By selecting an appropriate inspection level to begin with, and providing suitable means for changing the inspection level in accordance with the state of process control, the engineer will be able to reduce or minimize his inspection costs.

The following is a summary of the steps to be taken in keeping inspection costs low.

(1) Set up process controls in the Operating organization (including sorting by Operating if necessary) such that the product that leaves Operating will, under normal conditions, meet the shipped quality standards.

(2) For normal use give Inspection a sampling plan which calls for relatively small samples. The samples may be too small to protect the quality standards by themselves, but they must be large enough to detect a breakdown in the Operating controls.

(3) For use when the Operating controls break down, give Inspection a tighter plan which will, under emergency conditions, place the necessary protective power in the hands of Inspection.

(4) Concentrate on restoring the Operating controls as soon as possible, in order to get rid of the uneconomical inspection.