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MILITARY HANDBOOK

GUIDE FOR ATTRIBUTE LOT SAMPLING INSPECTION AND MIL-STD-105

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MIL-HDBK-53-1A
Guide for Attribute Lot Sampling
Inspection and MIL-STD-105
1 February 1982

1. This standardization handbook is approved for use by the Armament Materiel Readiness and Armament Research and Development Commands, Department of the Army, and is available for use by all departments and agencies of the Department of Defense. MIL-HDBK-53-1A is Part 1 of three parts.

2. This part provides basic information on sampling inspection, especially attribute lot sampling inspection, and on MIL-STD-105. The information in this and each of the following parts should be helpful to anyone involved with sampling inspection including quality managers, engineers, specification writers, and inspectors. Where the handbook appears to be in conflict with any sampling standard, the material in the standard shall take precedence.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Armament Research and Development Command, ATTN: DRDAR-TST-S, Dover, NJ 07801.

CONTENTS

PAGE

PAGE

PAGE

FIGURES

TABLES

GUIDE FOR SAMPLING INSPECTION

SECTION 1: INTRODUCTION

1.1 Purpose. This handbook is a guide for the basic principles of sampling inspection. Its purpose is three fold:

a. to describe basic sampling procedures,
b. to explain the basic principles underlying attribute lot sampling inspection and,
c. to demonstrate how sampling plans, including those established by certain sampling standards, handbooks, and related documents, are used in arriving at appropriate inspection and quality assurance decisions.

1.2 Scope. This handbook may be useful to quality managers, engineers, specification writers, inspectors, and others who are concerned with sampling inspection problems. It discusses some of the basic principles of sampling inspection and provides the framework necessary for proper application of sampling inspection. It is written in three volumes:

MIL-HDBK-53-1 Guide for Attribute Lot Sampling Inspection and MIL-STD-105
MIL-HDBK-53-2 Guide for Attribute Continuous Sampling Inspection and MIL-STD-1235
MIL-HDBK-53-3 Guide for Variables Lot Sampling Inspection and MIL-STD-414.

In this volume, Part A deals primarily with general attribute lot sampling procedures. Occasional reference is made to variables lot sampling and attribute continuous sampling to compare these procedures with attribute lot sampling procedures. Part B is an extension of Part A, but deals specifically with attribute lot sampling plans as set forth in MIL-STD-105. A reading list is furnished in Appendix A, and mathematical formulas and curves relating to attribute lot sampling are presented in Appendix B and Appendix C.

1.3 Application. This handbook has been specifically prepared for use by inspection personnel responsible for inspection decisions of an operational nature. It may be used as a guide in establishing procedures for determining conformance of operations, data, inventory control, etc., to prescribed quality standards.

1.4 Credits. Portions of this handbook were reprinted with permission from (U.S. copyrighted) International Organization for Standardization Standard ISO 2859-1974/Addendum 1 (1977), (See

Appendix A). The sections or paragraphs which are taken in part or whole from the ISO Standard are: 3.2, 13, 18 (except 18.1), 21, 22, 23, 24.3, 25, 26 (except 26.5), 27 (except 27.2d), 28 (except 28.5), 29, 30, 31.1, 31.4, 31.5, 32, 36.1, Example 27.

PART A: GENERAL INFORMATION ON SAMPLING INSPECTION

SECTION 2: UNIT OF PRODUCT

2.1 Definition. The unit of product is the thing inspected in order to determine its classification as defective or nondefective or to determine the number of its defects.

2.2 Examples. The unit of product may be a single article, a pair, a dozen, a gross, or a set of stated quantity. It may be measured in terms of one or more of its characteristics such as a length, an area, a volume, a weight, or any other suitable measurement. The unit of product may be a raw material, a material in process, a component of an end product, the end product itself, or a material in storage. The unit of product may also be an operation such as production, procurement, maintenance, or a storage operation. It may be an administrative procedure, a punched card, a government bill of lading, an inventory stock record card, a magnetic or paper tape containing recorded data or any form of data or records. It may or may not be the same as the unit of purchase, supply, production, or shipment.

2.3 Homogeneity. Homogeneity implies that a series or group of units are alike or similar in nature but are not expected to be identical under detailed inspection. More specifically, homogeneity implies that a series or group of units are produced:

a. from the same batches of raw material, components, or subassemblies;
b. on the same production or assembly line with the same molds, dies, patterns, personnel, etc.; and
c. during a unit of time such as an hour, a day, a week, a shift, etc.

2.4 Quality Characteristics. Quality characteristics are those properties of a unit of product that are to be evaluated against the specific requirements of a drawing, specification, model, or other standard. For example, if a specification states that the diameter, the hardness, and the weight of a ball bearing must lie within certain limits in order to be acceptable, then the diameter, the hardness, and the weight are quality characteristics of the ball bearing for the purposes of the specification. The design of the unit of product must be analyzed in order to list the quality characteristics. Specifications, purchase descriptions, drawings, or product descriptions are the normal sources of the requirements which a unit of product must meet to satisfy the needs of the consumer.

SECTION 3: NONCONFORMANCE

3.1 General. Nonconformance is defined as the failure of a unit of product to meet specified requirements.

3.2 Defects and Defectives. A defect is any nonconformance. Para. 2.4 lists several types of documents in which the specified (specific) requirements for a unit of product may be found. A defective is a unit of product which contains one or more defects.

3.2.1 Classification of Defects. The classification of defects and defectives is the listing of possible defects of the unit of product according to their importance. The discussion so far has assumed that, if an article can be defective in more than one way, the different possible defects are all of equal importance. Under this assumption, it is possible to dispose of the lot by simply counting the defectives. For example, if there are three dimensions (A, B, and C) to be checked and, in a sample, 3 articles are defective in dimension A alone, 3 articles in B alone, 1 article in C alone, and 1 article in both A and B, there is a total of 8 defectives, which is the number to compare with the acceptance and rejection numbers (see 7.2 for definitions of acceptance number and rejection number).

3.2.2 Inspection by Class. But this simple procedure of adding defectives of different types is reasonable only if the defects are of equal, or nearly equal, importance. Where this is not so, it is necessary to classify the possible defects into groups or classes so that defects in the different classes are of different orders of importance, but all defects within a class are of approximately the same order of importance. Different sampling plans may then be used for an entire class or for some part of an entire class. Applying a sampling plan to an entire class or to a part of a class of defects of a unit of product instead of only to a single defect is called inspection by class. Inspection by class allows a great deal of flexibility in carrying out the quality function. It should be noted that defect classes and inspection classes are not the same. A defect class is a group of quality characteristics of the unit of product that are subjected to the same sampling plan. (See Section 7). Inspection by class is discussed further in Section 30.

3.2.3 Common Defect Classes. Many inspection systems use three classes of defects, namely critical defects, major defects, and minor defects. The class of critical defects is the most important class of defects and is discussed separately in para. 3.2.5 and 3.2.6. Major defects are those defects which render the article useless or practically useless, and minor defects are those which make the article less useful than they should be, but not seriously so. While these three classes are sufficient for many inspection situations, other classes or subclasses may be used where helpful. It should be realized that defect classes are used to deal with the relative importance of different defects within any given product, and since products themselves vary in importance, the classes do not correspond to any absolute standards of importance. There is, therefore, no particular sampling plan that normally goes with any class.

3.2.4 Classification of Defectives. Different methods are used to classify defectives. Both methods described here use defective class names that are the same as or nearly the same as the defect class names (e.g. critical, major, minor) used by that method. The method probably used most often classifies a defective according to the most serious defect found on it. (See MIL-STD-105, for example). That is, if a unit of product is found to have both major and minor defects, say, then the unit is classified as a major defective. Another system for classifying defectives classifies a defective according to the defects found on it. That is, if a unit of product has both major and minor defects, it is classified as both a major and a minor defective.

3.2.5 Critical Defects and Defectives. According to the definition of a critical defect in MIL-STD-105, this classification should be used for a defect that is likely to cause hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product. The critical classification is also to be used for a defect that is likely to prevent performance of the practical function of a major end item. The wording "is likely to" is important. There is sometimes a tendency to replace these words by "could possibly" and hence to classify everything as critical, since it is always possible to make up a story in which some trivial happening at the beginning leads to catastrophe at the end. If this approach is adopted, the main result is to devalue the critical classification, and the genuine criticals may not be treated as severely as they should be.

3.2.6 Inspection Level for Critical Defects. Because critical defects are a category of such severe defects, the lot is rejected anytime a critical defect is found during inspection. This means that when inspection is destructive or very expensive and, therefore, only a sample of the lot is being inspected, the acceptance number (7.2) will be zero. However, the solutions usually adopted, where inexpensive (relatively) or nondestructive inspection are involved, is to specify that inspection for critical defects will use a sample size equal to lot size and an acceptance number again equal to zero. It should be noted that this is 100% inspection, not 100% sorting. Finding critically defective product does not simply result in separate piles of product, defective and nondefective, but in lot rejection (although rejection does not necessarily mean scrapping. See Section 14). Whenever possible, it should also mean that production is stopped while a thorough investigation takes place to attempt to discover how the defect arose and to devise methods to prevent another occurrence. The reason for this procedure is to try to prevent the production of critical defectives and to avoid giving the manufacturer the impression that since the inspector will sort them out for him it will not matter too much if he produces some. Even the best inspector may occasionally fail to notice a defect, so it is only by preventing critical defectives from being made that it can be ensured that none will get through to the customer.

3.3 Expressions of Nonconformance. The extent of nonconformance of product to the specified quality characteristics may be expressed either in terms of percent defective or defects per hundred units. MIL-STD-105 requires that nonconformance be expressed using one or the other of these terms.

3.3.1 Percent Defective. The percent defective of any given quantity of units of product is one hundred times the number of defective units of product contained therein divided by the total number of units of product therein:

$$\text{Percent defective} = \frac{100 \times \text{defectives in the quantity.}}{\text{Number of units}}$$

An estimate of the percent defective in a quantity of units is obtained by selecting a random sample for inspection, determining the total number of defectives in the sample, multiplying by one hundred, and dividing the result of the multiplication by the number of units in the sample:

$$\text{Estimate of percent defective} = \frac{100 \times \text{defectives in sample}}{\text{Number of units in sample}}$$

3.3.2 Defects per hundred units. The number of defects per hundred units of any given quantity of units of product is one hundred times the number of defects contained therein (one or more defects being possible in any unit of product) divided by the total number of units of product:

$$\text{Defects per hundred units} = \frac{100 \times \text{number of defects}}{\text{Number of units}}$$

An estimate of defects per hundred units in a quantity of units is obtained by selecting a random sample for inspection, determining the total number of defects in the sample units, multiplying this number by one hundred, and dividing the product by the number of units in the sample:

Estimate of defects per hundred units

$$= \frac{100 \times \text{number of defects in the sample units}}{\text{Number of units in the sample}}$$

For this expression of nonconformance, each unit of product must be examined to determine all defects that may be present. It should be noted that when units of product have more than one quality characteristic, the upper limit to the expressions of nonconformity discussed in this paragraph will exceed 100. This contrasts with an upper limit of 100% in all cases for both expressions of nonconformity in the previous paragraph.

3.3.3 Process Average. The process average is the average percent defective or the average number of defects per hundred units (whichever is applicable) of product submitted by the supplier for original inspection. Orginal inspection is the first inspection of a particular quantity of product as distinguished from the inspection of product which has been resubmitted after prior rejection (see 14.1). See Section 15 for computation of the estimate of the process average.

SECTION 4: INSPECTION

4.1 General. Inspection is the examination or testing of supplies and services (including, when applicable, raw materials, documents, data, components, and intermediate assemblies) to determine whether the supplies and services conform to technical and contractual requirements. The prime values of inspection are that it:

a. separates acceptable from unacceptable products, operations, procedures, or records;
b. evaluates the degree of conformance or nonconformance to established requirements;
c. provides for reporting of deficiencies early in the operation of the manufacturing, business, or management process; and
d. assures the desired quality requirements have been met.

The inspection criteria used to determine whether the quality requirements have been met are stated in appropriate documents such as: purchase descriptions, project descriptions, inspection instructions, technical orders, drawings, technical bulletins, and military specifications.

4.2 Amount of Inspection. Before deciding how much inspection should be done in a particular situation, one (who is responsible for deciding) must realize that for a given acceptance criterion, the less of that inspection that is done, the greater becomes the risk that nonconforming product will be accepted. Methods for assessing the risk that accompanies a given sampling plan (see 7.1 for the definition of one type of sampling plan) are discussed in Section 10. Also, before a decision can be made on the amount of inspection, it must be determined how units of product will be submitted for inspection, whether on a lot-by-lot basis or on a unit-by-unit basis (Section 6). Once the above questions have been understood and answered, the following factors are among the most important that might be considered when deciding the amount of inspection:

a. the type of product to be inspected;
b. the quality characteristics to be examined for conformance;
c. the quality history of the producer;
d. the cost of inspection; and
e. the effect of inspection upon the unit of product (i.e., destructive or nondestructive).

The question of how much inspection should be done is related to the problem of selecting a sampling plan. This latter problem is discussed in Section 8 and in 10.3.1. In Section 8, a number of factors are listed which will affect the selection of a sampling plan. Several of those factors, in addition to a-d above, also affect the amount of inspection decided upon. Because of this interdependence between these two questions, it is suggested that they be studied and considered together.

4.3 One Hundred Percent Inspection. One hundred percent inspection is the inspection of every unit of product (procedure, data, operations, etc.). In some cases of one hundred percent inspection, the accept/reject decision will be made not for the entire lot, but for each unit individually, based upon the results of inspecting the unit for the quality characteristics concerned. For certain quality characteristics (e.g., critical), one hundred percent inspection or inspection of relatively large samples is usually required to assure the desired quality protection. One hundred percent inspection cannot be specified when inspection is destructive and is not likely to be specified when the individual tests are expensive or take extremely long periods of time--for example, qualification and environmental tests. One hundred percent testing can always be specified for nondestructive tests, that is, for tests where the characteristic can be measured without damaging the product.

The obvious advantage of one hundred percent inspection is that it gives a better indication of product quality than does sampling inspection. Generally, however, one hundred percent inspection does not guarantee detection of all defects, especially when the inspection is done by human inspectors. The direct costs of one hundred percent inspection will generally be greater than costs of sampling inspection. However, the cost of permitting a defect to go undetected may be so great that the cost of one hundred percent (or even two hundred percent or three hundred percent) inspection is justified.

4.4 Sampling Inspection. Sampling inspection is that type of inspection wherein a sample consisting of one or more but not all units of product is selected at random from the production process output and examined for one or more quality characteristics. Sampling inspection is usually the most practical and economical means for determining the conformance or nonconformance of product to specified quality requirements. Sampling inspection has the advantage of flexibility with regard to the amount of inspection to be performed at any given time, depending upon the importance of the product and apparent product quality. The amount of inspection can be reduced for product of very high quality, or increased when the product quality is deteriorating. Sampling inspection costs are generally lower than one hundred percent inspection costs since sampling inspection does not require that each unit of product be inspected for conformance with specified quality requirements. However, when determining which inspection method is to be employed, the lower costs of sampling inspection must be weighed against the risk of greater cost incurred by permitting defective units of product to be accepted.

4.5 Verification Inspection. A special kind of inspection, the purpose of which is not explicitly described in paragraph 4.1, is performed to determine the validity of original sampling inspection of a product. This type of inspection, called verification inspection, is further discussed in paragraphs 17.1 and 17.4.

SECTION 5: METHODS OF INSPECTION

5.1 General. There are two recognized methods of inspection for evaluating quality characteristics, and those two methods are known as attributes inspection and variables inspection. Since attribute lot inspection is the primary topic of this volume, variables inspection is discussed only briefly here. MIL-HDBK-53-3 deals with variables inspection in greater detail.

5.2 Attributes Inspection.

5.2.1 Attribute. An attribute is a characteristic or property which is appraised in terms of whether it does or does not meet a given requirement, e.g., too big or not too big; hard enough or not hard enough.

5.2.2 Inspection by Attributes. Inspection by attributes is inspection in which certain characteristics of units of product are classified simply as defects or nondefects. Any unit of product found to have one or more defects is classified as a defective. Under attributes inspection, characteristics of the units of product are considered on the basis of "go, not go," "defective, nondefective," "within tolerance or out of tolerance," "correct or incorrect," "complete or incomplete," etc.

5.2.3 Applications. Attributes inspection is used in examining items for visual defects, missed entries or operations, workmanship defects, incorrect dimensions, defects in materials, marking, packing and packaging, and for examinations or tests where the characteristic involved is checked to determine solely whether it does or does not meet the established requirements.

5.2.4 Advantages. Inspection by attributes is usually simpler and less expensive than inspection by variables (5.3) because the following are usually true: the inspection itself can be done more quickly and easily, less detailed record keeping is required, and administration of the inspection is easier. For example, it may be more economical to inspect for a particular dimensional characteristic on 100 units for inspection by attributes using fixed gages than to measure 60 or 70 of the same units for inspection by variables with standard measuring instruments. When inspection is by attributes, record keeping and administration may be simplified by grouping together all quality characteristics of equivalent importance and establishing one quality level for the group as a whole. (This technique, known as inspection by class, is discussed in Section 30.) Under variables inspection, by contrast, methods have not been developed for determining compliance with one quality level for a group of quality characteristics considered collectively. An individual quality level must be set for each characteristic, and a separate decision is made to accept or reject for each characteristic.

5.2.5 Disadvantages. Attribute inspection has perhaps only one disadvantage, and that is that it requires a larger sample to obtain the desired amount of information about the parent lot than does variables inspection. This disadvantage becomes significant when inspection of individual units of product is expensive either in terms of dollars or time.

5.3 Variables inspection.

5.3.1 Variable. For inspection purposes, a variable is a characteristic or property which can be measured and the measurement expressed in terms of some continuous scale. Examples of such characteristics and scales used to measure these are: time - seconds, minutes, hours; length - feet, meters; weight - pounds, grams.

5.3.2 Inspection by variables. Inspection by variables is inspection in which a quality characteristic of each unit of product in a sample is measured, and the accept/reject decision for the lot is made based usually upon the sample mean and some measure of the spread of the sample measurements (e.g., standard deviation or subsample ranges). Hence, when inspection is by variables, the lot is evaluated using a numerical, continuous scale measurement instead of the "go, not go" measurement that is used with attribute inspection (5.2). In MIL-STD-414, the primary variables inspection military standard, the accept/reject decision is made after the sample statistics have been used to obtain an estimate of the lot percent defective.

5.3.3 Applications. Inspection by variables can be used whenever the quality of any given characteristic of a unit can be determined in quantitative or measurable terms. Variables inspection can be applied to such characteristics as weight, tensile strength, dimensions, chemical purity, burning time of smoke munitions, etc. A specific example is as follows:

A specification requirement on a type of hand tool specifies a Rockwell C Scale hardness reading from 50 to 55. A hardness check on a sample of five hand tools picked at random yields readings of 53, 50, 52, 51, 50. These test results clearly show that the five sample units fall within the specification limits. The extent to which each sample unit is within the limits can be measured. These data not only show whether the specification requirements have been met, but also give an indication of the degree of variation within the quantity of product from which the sample was selected.

5.3.4 Advantages. In comparison with attributes sampling plans, variables sampling plans provide considerably more information regarding the conformance or nonconformance of the particular quality characteristic. For this reason, variables sampling plans have the advantage of usually requiring smaller sample sizes for equivalent assurance as to correctness of decisions to accept or reject a quantity of product. This smaller sample size is especially important where destructive testing is to be done or where the cost of testing each additional unit of product is high. However, if a number of quality characteristics are to be evaluated on the basis of variables inspection, the cost of inspecting each unit in the sample on an individual characteristic basis may be so high that this factor greatly offsets the advantage of reduction in sample size.

5.3.5 Disadvantages. While attributes inspection can be applied to the inspection of most characteristics, variables inspection requires that the measurements of the characteristic in question follow, at least roughly, a specified statistical distribution, usually the normal distribution. Hence, there should be some assurance that the parent population follows the distribution. This assurance can be gained either through a test of the sample at hand or through the history of the population. (MIL-STD-414 does not require any assurance, but only suggests that advice be obtained when the distribution is in doubt.) If a test of the sample is used and is negative, the next step will be either to ignore the test results and analyze the inspection data as though its parent population followed the assumed distribution or to analyze the inspection data using attribute methods. If the latter procedure is selected, it will be necessary to decide whether or not to draw an additional sample sufficient to provide protection that is equivalent to the originally planned variables test. Inspection personnel should check with item specifications, test procedures, or higher headquarters for the procedure to follow in case the test for the distribution is negative. Variables inspection further requires that inspection personnel be trained sufficiently to make the more complex variables measurements, computations, and decisions. However, variables computations, though still more complex than those for attributes inspection, have been greatly simplified with the development of relatively low priced hand calculators. These machines have made computations possible in less time and with less chance of error than was possible previously.

5.4 Converting Variables to Attributes. The results of variables inspection for a given quality characteristic can be converted to attributes. At the discretion of the responsible authority, this conversion may be made even though the requirement is expressed as a variable. For example, a specification establishes a sleeve length of 22 inches with a tolerance of plus or minus 1/2 inch as a requirement on a certain type of apparel. Since a measurable characteristic is involved, on a numerical scale, variables inspection could be employed. However, attributes inspection can be used instead. A sleeve measuring anywhere between 21 1/2 and 22 1/2 inches would be classified as nondefective, and a unit with a sleeve measuring less than 21 1/2 inches or more than 22 1/2 inches would be classified as defective. When such conversion is decided upon, the appropriate sampling standard (such as MIL-STD-105) should be consulted to insure that the level of protection is maintained.

SECTION 6: SUBMISSION OF PRODUCT

6.1 General. Units of product may be submitted, i.e., considered for inspection, on the basis of a continuous production flow; or they may be separated into lots or batches for lot-by-lot, skip or isolated lot inspection.

6.2 Continuous Sampling Inspection. Under continuous sampling inspection, units are produced and submitted consecutively for inspection in the order produced. The products may be presented on a moving conveyor belt as they come from a continuous production line. Continuous sampling inspection of the product may be required or desirable when:

a. Storage facilities are inadequate or it is otherwise impractical to accumulate products into lots or batches for the purpose of inspection; or

b. The assembly of small lot sizes greatly increases the amount of inspection and thus results in increased inspection costs.

Under these or other conditions, it may be appropriate to consider use of continuous sampling plans to determine the acceptance or rejection of units of product. Continuous sampling is covered in greater detail in MIL-HDBK-53-2 and in MIL-STD-1235, Single- and Multi-level Continuous Sampling Procedures and Tables for Inspection by Attributes.

6.3 Lot-by-Lot Sampling Inspection. Lot-by-lot sampling inspection requires each individual lot to be accepted or rejected as a whole, based on inspection results obtained from a sample or samples drawn at random from the lot. Lot-by-lot sampling inspection may be applied on end products, incoming lots or batches of components, or semi-finished products. It may be performed by drawing the sample after submittal of the entire lot (i.e., stationary lots), or by drawing the units for inclusion in the sample concurrently with production of the lot (i.e., moving lots, see 6.4.2).

6.4 Formation of Lots. The formation of inspection lots is the procedure of assembling the units of product into identifiable lots, sublots, batches, or in such other manner as may be prescribed. Each lot or batch shall, as far as is practical, consist of homogeneous units of product (see 2.3). The procedures to be followed in the formation of the lot are very important since the disposition of the lot is determined by the results of sampling inspection. Advantages in grouping the product for lot sampling inspection include:

a. Facilitates maintenance and continuity of lot quality history;

b. Makes it possible to establish a system for controlling the serviceability status of products in storage and use after the product has entered supply channels.

6.4.1 Inspection Lot Size. The inspection lot is a collection of units of product from which a sample is to be drawn and inspected to determine conformance with the acceptance criteria, and may differ from a collection of units designated as a lot or batch for other purposes (e.g., production, shipment, procurement, etc.). The size of the lot or batch is one of the factors that determines the sample size to be used in lot sampling inspection.

a. Large Lots. In general, the ratio of sample size to lot size decreases as the lot size increases. Therefore, formation of larger lot sizes tends to reduce inspection costs. Small production lots may be combined, when conditions of homogeneity are satisfied, to form a larger lot called a "grand" lot. The grand lot is sample inspected as a single large lot.

b. Small Lots. The formation of very large lots may be undesirable since it may create an expensive storage problem, disrupt the flow of product to the consumer on a fixed delivery schedule, and may cause difficult problems if rejection occurs. For large lots, inaccessibility to all units in the lot may make it more difficult to obtain a random sample. Under certain conditions, this problem may be minimized by subdividing the lot into sublots for purposes of sampling inspection. For example, if the lot represents a full week of production, each inspection sublot may consist of one day's production. Each day's production is then accepted or rejected based upon the results of a sample inspection. Care must be taken to maintain lot identity and records of sublot inspection results in case later events should require that these items be recalled (see 6.6). Another possibility for handling the large lot problem is to apply a sampling plan to the entire week's production. However, a portion of the sample is drawn from each day's production proportional in size to the amount of production for the day. The acceptance/rejection criteria are then applied to the inspection results accumulated over the week.

6.4.2 Moving Inspection Lots. A moving inspection lot consists of units of product continuously offered for inspection in the order produced or received, similar to (but not to be confused with) the procedure for continuous sampling inspection. The beginning and ending of the lot is identified against time (e.g., the production for one hour, one shift, one day, one week, etc.) or a specified quantity of units (e.g., 100, one gross, 500, etc.). Since products in a moving lot may pass the inspector piece by piece, the task of selecting a representative random sample is much simpler than drawing a random sample from a large stationary lot. For moving lots, the supplier does not have to accumulate and inventory for inspection. The accept/reject criteria is applied to the entire lot, just as with a stationary lot.

6.5 Skip Lot Sampling. Skip lot sampling provides a method for reducing inspection costs by allowing certain of the lots in a string of lots to be accepted without first undergoing acceptance inspection. Of course, the price to be paid for not inspecting all lots is the increased risk of accepting poor quality lots of product. Hence, one of the criteria for using skip lot sampling should be the ability of the supplier to submit products of consistently high quality as proven in the quality history of the product.

6.5.1 Skip Lot Sampling Plans. Skip lot sampling requires alternating lot-by-lot sampling phases (skip lot plans usually begin with this phase) with phases in which only a fraction of the lots are sampled (and the remainder of the lots are skipped). The procedure calls for a switch from a period of lot-by-lot sampling to a period of skip sampling any time a specified consecutive number of lots have been accepted. When a lot is rejected during skip sampling, either the fraction of lots selected for sampling is increased or lot-by-lot sampling is resumed. (This latter choice would be the one usually taken.) Once a lot has been selected to be skipped, that lot has been accepted by the consumer. However, once an inspected lot is rejected during a skip phase, the skip lot procedure may require a recall for inspection of all lots accepted by skipping after the last inspected and accepted lot. Whether or not this recall is included in the skip lot procedure will depend, in part, upon the nature of the product and the ease of inspecting already accepted lots. A variety of skip lot plans are possible. One of the factors that must be considered in selecting one of these plans is its complexity and, thus, how difficult it will be to administer. The plan finally selected should, of course, be no more complicated than necessary. Multi-level Continuous Sampling Procedures and Tables for Inspection by Attributes, provide several patterns that can be used for constructing skip lot sampling plans. Constructing a plan in this way is done simply by treating the inspection lot in the skip lot problem as the unit of product in a continuous sampling plan. The construction or selection of a skip lot sampling procedure for a particular product and production situation is beyond the scope of this handbook. It is recommended that knowledgeable quality assurance personnel be consulted for assistance. While Example 1 below does not refer to MIL-STD-1235, the skip lot plan that is described is patterned after a CSP-1 type continuous sampling plan.

6.5.2 Selection of Skip Lots. A random process should be used to select which lots are to be sampled and which lots are to be skipped. Methods of random selection are described in Section 12 of this handbook.

Example 1: A Skip Lot Plan: A producer has been manufacturing a product for a government agency for two years and has been successful in maintaining process control as well as achieving a high percentage of lot acceptance. The producer approaches the agency with a proposal for replacing the present lot-by-lot sampling inspection with a skip lot sampling plan. The agency's quality assurance representative is initially unfavorable because the producer's proposal calls for lot inspection using an attribute lot sampling plan identical to the one in use with the lot-by-lot plan. However, when the producer points out the significant price reductions and the speed-up in the production schedule that could be realized with the new procedure and when he points out the production record of the past two years, the agency's purchasing agent persuades the quality assurance representative to concur in the change. The producer's proposed plan calls for lot-by-lot sampling inspection until ten consecutive lots are accepted and then a skip lot inspection phase in which sampling inspection is performed on an average of one out of every four lots. During the skip lot phase, lots are to be selected for sample inspection by some random process (see Section 12) with the restrictions (1) that the selection of a lot for inspection or skip shall not be made until production of that lot is completed and (2) that no more than four consecutive lots shall be uninspected.

6.6 Lot Identity. Proper lot identification and effective maintenance of inspection results for each lot are essential. Arrangements for the formation of inspection lots should include provisions for the identification and segregation of inspection lots. Maintenance of lot identity will assure that acceptance or rejection is made on the lot from which the sample was drawn. Maintaining lot identity will prevent mixture of rejected product with other products not yet inspected, or accepted product awaiting shipment. The simplest way to maintain lot identity is by physical segregation. This facilitates the disposition of the inspected product, whether the decision is to accept or reject the lot. In case of lot acceptance, segregated lots are most easily marked for shipment. In the case of lot rejection, segregated lots can be readily identified for screening and resubmittal if such action is warranted or desired. In case problems are discovered with units of product within a lot after the lot has been accepted, two steps are essential: (1) proper lot identification for tracing remaining units of the lot to determine if they also share the problem, and (2) maintenance of inspection results for determining the early history of the lot and tracing the source of the problems. The history of problems in the field reveals that problems are usually discovered when individual units give trouble. This is usually long after they have been separated from the lot. Hence, it is practically impossible to identify the lot unless the units themselves carry some identification mark.

6.7 Isolated Lots. An isolated lot is one that has been placed apart by itself. The term isolated lot is used broadly to describe lots that are removed from the influence of the production process. For example, when five consecutive production lots are shipped to five widely scattered depots, each lot becomes an isolated lot at the depot receiving stations. Another example is the production of only one lot that is also the inspection lot, thus making it an isolated lot as far as that type of product is concerned. The term isolated lot, as used in the sampling procedures by the Department of Defense, actually refers to those sampling plans where the limiting quality (LQ) and consumer's risk are applied (see 9.3 and 10.2). The lots do not have to be isolated, in a physical sense, before applying these concepts to sampling inspection procedures.

SECTION 7: TYPES OF ATTRIBUTE LOT SAMPLING PLANS

7.1 General. An attribute lot sampling plan is a statement of the sample size or sizes to be used and the associated acceptance and rejection numbers. The acceptance number is the maximum number of defects or defective units in the sample that will permit acceptance of the inspection lot or batch. The rejection number is the minimum number of defects or defective units in the sample that will cause rejection of the lot represented by the sample. Attribute lot sampling plans can be grouped into four basic types: single, double, multiple, and sequential. The use of single, double, multiple, and sequential sampling plans usually requires the grouping of production units into lots or batches. Lots or batches are either accepted or rejected depending upon the results of sampling inspection. It should be understood that the terms "accepted" and "rejected" indicate a statistical decision reached on the basis of the sampling plan used. This decision in itself does not dictate or guarantee final acceptance or rejection, since other contractual, administrative or technical considerations may be involved. The primary purpose of sampling inspection is to obtain information in order to reach a statistical decision regarding the disposition of lots or batches (accepted if they conform to specified quality requirements, or rejected if they do not conform).

7.2 Single Sampling. A single sampling plan is a type of sampling plan by which the results of a single sample from an inspection lot are conclusive in determining its acceptability. The number of sample units inspected will be equal to the sample size given by the plan unless the item specification permits curtailment of inspection (See Section 13). This number is usually designated by the letter "n". If the number of defectives found in the sample is equal to or less than the acceptance number (usually designated by "Ac" or "c") the lot or batch shall be considered acceptable. If the number of defectives is equal to or greater than the rejection number (usually designated by "Re" or "r") the lot or batch should be rejected. For example, a single sampling plan for a lot of 700 units of some product might require a sample of size n = 80 units with an acceptance number of Ac = 3 and a rejection number of Re = 4. Since a single sampling plan accept/reject decision is to be made for a lot based on inspection results for a single sample, the accept and reject numbers for the plan must be consecutive, positive integers as shown in this example. (See 28.3 for an exception to this rule.)

7.3 Double Sampling. A double sampling plan involves sampling inspection in which the inspection of the first sample leads to a decision to accept, to reject, or to take a second sample. The inspection of a second sample, when required, then leads to a decision to accept or reject. Double sampling plans are operated in the following manner:

a. A first sample of n_1 units is selected at random from the lot and inspected. If the number of defectives is equal to or less than the first acceptance number, c_1, the lot is accepted. If the number of defectives is equal to or greater than the first rejection number, r_1, the lot is rejected. If the number of defectives is greater than the first acceptance number, c_1, and less than the first rejection number, r_1, the next step in the sampling plan must be taken.

b. A second sample of n_2 units is selected at random from the lot and inspected. The number of defectives found in the second sample is added to that found in the first sample. If the cumulative number of defectives is equal to or less than the second acceptance number, c_2, the lot is accepted. If the cumulative number of defectives is equal to or greater than the second rejection number, r_2, the lot is rejected. Note that r_2 equals c_2+1 so that a decision to accept or reject is forced on the second sample. Under certain conditions it may be more desirable to select both samples of a double sampling plan at one time, rather that draw the second sample after the first sample has been inspected. Inspection of the second sample would not be required if the lot is accepted or rejected based on the inspection results of the first sample.

7.4 Multiple Sampling. Multiple sampling or sequential sampling is a type of sampling in which a decision to accept or reject an inspection lot is reached after one or more samples from the inspection lot have been inspected and will always be reached after not more than a designated number of samples have been inspected. Although many writers use the terms multiple sampling and sequential sampling interchangeably, in this handbook another common usage will be adopted. Multiple sampling will refer only to the type of sampling described in this paragraph, while sequential sampling will refer only to item-by-item sequential sampling described in 7.5. The procedure for multiple sampling is similar to that described for double sampling, except that the number of successive samples required to reach a decision to accept or reject the lot may be more than two.

7.5 Item-by-Item Sequential Sampling. Item-by-item sequential sampling (or simply sequential sampling) is a sampling plan in which the sample units are selected one at a time. After each unit is inspected, the decision is made to accept the lot, to reject the lot, or to inspect another unit. Sampling terminates when the cumulative inspection results of the sample units determine that the acceptance or rejection decision can be made. The sample size is not fixed in advance, but depends on actual inspection results. It may be possible to continue sampling under the sequential plan until all units are inspected. From a practical standpoint, this is not desirable and is seldom required. Most sequential sampling plans are "truncated," which means the plan requires either an acceptance or rejection decision after a specified number of units have been inspected. It should be emphasized that for a large majority of lots, the total sample size under sequential sampling will be smaller than under single or double sampling. See 8. and 11. in Appendix A for further details and examples dealing with sequential sampling.

7.6 ASN Curves. Average sample number (ASN) curves are a graphic means of showing the average sample sizes which may be expected to occur under the various sampling plans for a given product quality. The average amount of inspection for any sampling plan can be computed. On the average, double sampling plans usually require less inspection than single sampling plans, and multiple sampling plans usually require less inspection than double sampling plans. Usually, the amount of inspection required for single sampling is the number of units in the sample, regardless of the product quality, unless inspection is curtailed (i.e., immediately terminated) as soon as the rejection number is reached. For double and multiple sampling plans the amount of inspection is minimized when the product is of very good or very poor quality. Sequential sampling plans may result in a further reduction in the amount of inspection.

SECTION 8: SELECTION OF SAMPLING PLANS

In the preceding section, different types of sampling plans have been described and it has been shown that in many instances there are a number of alternative sampling schemes which can be used for a specific situation. The selection of a particular type of sampling plan, however, is not always an easy task since the selection is actually dependent upon a number of different factors. Generally, selection involves consideration of the following:

a. Properties of the sampling plan.
b. Ease of administering the sampling plan.
c. Protection afforded.
d. Amount of inspection required.
e. Cost of inspection.
f. The size of the lot.
g. The continuity of lots. That is, are the lots being inspected in sequence one after another from the same producer, or are they a series (of one or more) of isolated lots?
h. The cost to the consumer resulting from acceptance of a nonconforming item.
i. The cost of manufacturing the item.
j. The cost of delayed shipments.
k. The availability of product from other sources.
m. The consumer's past experience with product from the same producer.
n. The way the product is packaged.
o. The possibility of correcting nonconforming conditions during use.

In addition to the necessity for appropriately considering these factors, it must be recognized that the plan adopted for one type of product may not be the best for another type. This is particularly true where the submittal of product for inspection is dependent upon the physical layout of a manufacturing facility or operation, and/or the production methods. Further, past quality history of the supplier, source, or process, plays an important role in the selection of the appropriate sampling plan. Where this history shows submission of product of consistently high quality, a sampling plan should be selected which reduces the stringency of inspection (reduced sample size or larger acceptance number) required to reach an accept/reject decision on a lot. On the other hand, for suppliers, sources, or processes with relatively poor quality histories, more stringent inspection (increased sample size or smaller acceptance number) may be fully justified.

SECTION 9: GROUPING OR INDEXING OF SAMPLING PLANS

9.1 General. Several methods have evolved for grouping or indexing sampling plans. Most of these methods of grouping are based upon some aspect of producer and/or consumer protection offered by the plans that are being grouped. Following are some of the most commonly used methods of indexing or grouping sampling plans:

a. Indifference Quality Level (Pa = 0.5).
b. Limiting Quality (LQ) protection.
c. Average Outgoing Quality Limit (AOQL).
d. Acceptable Quality Level (AQL).

Because of the widespread availability and use made of MIL-STD-105 by both government and industry, suffice to state that since this standard makes use of AQL based sampling plans this group is the most widely used type of plan. However, tables of sampling plans based on LQ, AOQL, and Indifference Quality have also been developed. These four methods of indexing sampling plans are described more fully in the following paragraphs.

9.2 Indifference Quality (Pa = 0.5). Sampling plans based on the indifference quality are commonly called 50% plans. The indifference quality is that level of lot quality at which the probability of acceptance (Pa) is 0.5. The level of lot quality at which Pa = 0.5 depends, of course, upon the sampling plan being used for lot acceptance. (See Section 10 for discussion of OC curves). Products of better quality are accepted more often than they are rejected. Products of worse quality are rejected more often than they are accepted. A single sampling plan for the indifference quality level can be computed very easily by using the following approximate equation:

n = (100c + 67)/indifference quality (in percent defective) where n is the sample size and c is the acceptance number. For example, if a product that is 3% defective should be accepted with a probability of 50% and an acceptance number of 2 defectives is to be used, the sample size is computed as follows:

n = (100c + 67)/indifference quality (in percent defective)
n = (100x2 + 67)/3
n = 267/3
n = 89

The single sampling plan would be to draw a sample of 89 units at random from the lot. If 2 or less defectives are found, accept the lot. As long as the consumer and supplier do not care about their own specific risks at the quality level that divides tolerable quality from intolerable quality, this is a very simple way to perform sampling inspection.

9.3 Limiting Quality (LQ). The protection provided to the consumer by a sampling plan is usually described by the term "consumer's risk." The consumer's risk is the probability of accepting a lot the quality of which is at or below a level which the customer can tolerate, at most, a small part of the time. This quality level is called the limiting quality (LQ) or lot tolerance percent defective (LTPD). Sampling plans called LQ sampling plans may be devised to provide a specified LQ protection or consumer's risk protection when the product quality is at the LQ. Common values of the consumer's risk in LQ plans are 5% and 10%. These are very low percentages of lot acceptance that would be unsatisfactory for both the consumer and the producer. Hence, when the consumer specifies an LQ sampling plan, it is not with the intention that the LQ is a target quality level for the producer to meet, but rather a level to be exceeded by as much as possible. LQ sampling plans are most commonly used for isolated lots or batches (that is, lots produced on a one-of-a-kind or on an intermittent basis) where there is little or no opportunity to tighten inspection if product quality drops to an unacceptable level. A typical example of an LQ sampling plan is based on a statement by the consumer that he is willing to accept a maximum of 6.5% defectives (LQ = 6.5%) no more than 5% (consumer's risk = 5%) of the time. (See 10.2 for further discussion of consumer's risk.)

9.4 Average Outgoing Quality Limit (AOQL). The average outgoing quality (AOQ) is the average quality of outgoing product including all accepted lots or batches, plus all rejected lots or batches after they have been effectively screened and defectives removed or replaced by non-defectives. The average outgoing quality limit (AOQL) is the maximum AOQ for all possible incoming qualities for a given sampling inspection plan. Sampling plans which are selected to assure a desired AOQL are based on the assumption that rejected lots can and will be subjected to screening inspection. Plans of this type cannot be used where destructive type testing is the only means of determining conformance to specified quality requirements.

9.5 Acceptable Quality Level (AQL). The protection provided to the producer (supplier) by a sampling plan is usually given in terms of producer's risk. The producer's risk is the probability that a lot of acceptable quality is rejected, and the producer is "protected" when this probability is low. While the producer's risk is of interest, especially to the producer, at all levels of good quality, it is common practice to be especially interested in the producer's risk at the worst level of good or acceptable quality.

This level of product quality is called the acceptable quality level (AQL). The AQL is formally defined for lot sampling plans as the maximum percent defective (or maximum number of defectives per hundred units) that, for the purpose of sampling inspection, can be considered satisfactory as a process average. (See MIL-STD-1235 for a different meaning of the AQL when used with continuous sampling plans.) A sampling plan that is constructed or selected to provide a certain level of producer protection at the AQL is called an AQL plan. Different systems of AQL plans set the producer's risk at the AQL in different ways. For example, in order to provide a consistent producer's risk for all plans, Dodge's tables (see reference 21, Appendix A) have the producer's risk set at 5% at the AQL for all sample sizes. As another example, the sampling plans in MIL-STD-105 provide producer's risks that range from 1% to 15% at the AQL. As a rule, the producer's risk for these plans has been made smaller for the larger samples in order to reduce the risk of rejecting the larger and, therefore, more expensive lots from which they were selected. Ideally, AQL sampling plans also help to protect the consumer by providing a lower and lower probability of acceptance as product quality drops below the AQL. AQL plans are commonly used to inspect a continuous series of lots rather than isolated or intermittently produced lots. A typical AQL plan might be based upon a statement by the consumer that he will accept lots of product 97% of the time when the product average is 4% (AQL=4%) or better. (Producer's risk = Probability of rejecting acceptable product = 1 -.97 = .03 or 3%.) See 10.2 for further discussion of producer's risk.

9.6 Protection at Two Quality Levels. Sampling plans can be designed to provide combined AQL/LQ protection, AQL/Indifference Quality protection, or LQ/Indifference Quality protection. The most commonly used combination is probably the AQL/LQ type which provides a high probability (usually 90%-95%) of accepting a lot when the process average is at some acceptable level (AQL) and which provides a low probability (usually 5%-10%) of accepting a lot when product quality is low (LQ). In order for such sampling plans to be practical, there must be a reasonable numerical difference between the AQL and the LQ. A typical situation would be an AQL of 1.0 percent defective and an LQ of 6.5 percent defective. If the two quality levels (AQL and LQ) are very close together, one hundred percent inspection may be required to separate acceptable product from unacceptable product. The discussion of OC curves in Section 10 will provide further help in selecting sampling plans to meet protection requirements at two quality levels.

9.7 Selection of Quality Level. A large variety of sampling plans can be devised or selected on the basis of the level of protection offered to the producer and/or the consumer at a given quality level(s). The question which must be answered, then, is how much protection is to be offered at which quality level(s). The following paragraphs discuss qualitatively some of the factors which should be considered in answering this question.

9.7.1 General. The selection of a quality level value is the result of considering many factors. Some of these factors are the design requirements, quality protection required, unit costs, cost of inspection, process capabilities, defects or defect classes being considered, available quality data, and strictly military requirements which may outweigh all other considerations. These factors must be given their proper weight in reaching a decision as to which quality level value should be specified. Selecting extremely tight quality levels (low numerical values) might result in prohibitive inspection and end item costs, unnecessarily frequent rejection of products, or possible refusal by suppliers to accept procurement orders or sign contracts. On the other hand, selecting very liberal quality levels (high numerical values) might result in the delivery of large quantities of unsatisfactory products into the supply system.

9.7.2 Associated Risks. If a complete statement is to be made of a quality level requirement, an associated risk requirement must also be given. For example, with each high quality level, the associated supplier's risk should be stated (or implied as in the case of the AQL sampling plans). It is not enough to specify only a quality level. The probability of acceptance of product with this quality level must also be stated or implied. The OC curves for the resulting sampling plan will indicate graphically the relationship between the specified quality levels and their associated risks to the supplier and consumer. (See Section 10).

9.7.3 Process Capability. The state of the art, or the capability of industry to produce the product, may limit the selection of a quality level value. A review of suppliers' quality histories for a given product or similar products will provide an estimate of the product quality that can be reasonably expected under existing production capabilities.

9.7.4 Order of Assembly. If the production of defective units early in the order of assembly results in a large waste of time and materials during later processing or assembly, the quality level values set for these units should be tighter (lower numerical value) than might otherwise be expected. Selection of the proper quality level value depends on the type of product involved and the financial losses that might result. For example, it is much more expensive and time consuming to locate and replace a defective resistor inside a piece of complex electronic equipment than to replace an external knob that is defective.

9.7.5 Cost of Inspection. Quality level values frequently have a direct effect on the cost of inspection, especially when the quality levels are extremely high or low. If the quality level is very low (e.g., 650 defects per hundred units), only a very small sample may be required to determine acceptance or rejection of product. If the quality level is very high (e.g., 0.015 percent defective), a very large sample size may be required to determine acceptance or rejection of product. An increase or decrease in the sample size as determined in these cases by the specified quality level may result in increases or decreases in the related inspection costs.

9.7.6 Changing Quality Levels. The quality levels specified for most inspection situations should not be considered as fixed or permanent quality requirements. They are subject to change with the concurrence of the technical agency initiating procurement or the engineering agency responsible for design. Flexibility and the capability to make changes in quality levels are necessary steps to proper administration of inspection systems or quality programs. A continuous review of quality levels may be affected by changes to specification, improvements in production machinery or equipment, development of new production or inspection techniques, consumer complaints and other factors.

SECTION 10: SAMPLING RISKS AND OPERATING CHARACTERISTIC (OC) CURVES

10.1 General. Regardless of whether an inspection plan uses sampling or one hundred percent inspection, there is always a risk or chance that a small percentage of defective units will be passed. (This risk is greatly minimized if inspection is done by some dependable automated process.) Because of personnel errors, poor judgement in the interpretation of quality tolerances, improper use of inspection equipment, or incorrect conduct of tests, it is well recognized that there is always some risk that defective units may be missed under one hundred percent inspection, and even 200% or 300% inspection. This is not to infer that such mistakes are not made under sampling inspection, but that even when circumstances dictate its use, 100% inspection under optimum conditions is only 85 - 95% effective in separating bad product from good product (in the absence of completely automated processes). As with 100% inspection therefore, it logically follows that sampling inspection can never guarantee that material it has passed is completely free of defects, and, therefore, when any type of manual inspection is used, correct decision making for every lot, in the long run, is unlikely. In addition to the errors or mistakes in judgement which the inspector may make when using sampling inspection, there is also an additional statistical risk or sampling risk that the selected sample will not reflect the quality of the parent lot. It is this sampling risk, or luck of the draw, that is dealt with in later paragraphs in the development of operating characteristic curves.

10.2 Sampling vs. 100% Inspection. Hence, a decision must be made whether or not to use sampling inspection. The first consideration in making this decision for a particular quality characteristic is: "What would be the result of passing a defect?" If the defect is of such a nature that it could cause a safety hazard, incur great loss, result in intolerable operating inefficiency, or result in costly repairs or correction, the conclusion probably would be that sampling inspection should not be used because the presence of such defects could not be tolerated. Thus it would follow that even with its apparent limitations, 100% inspection should still be prescribed (see 4.3). If, on the other hand, the defect did not fall into any of the categories described above, the conclusion reached might be to use sampling inspection. Other factors relating to the question of choosing between 100% inspection and sampling inspection are dealt with in Sections 4 and 8.

If a sampling plan is properly chosen and executed, lots of "good quality" product will be accepted more often than rejected, and lots of sufficiently "bad" product will be rejected far more often than accepted. In certain production situations, "good" quality might mean a lot with no defective product while in other situations, because of the high cost of producing absolutely no defective product and because of the relatively noncritical use for which the product is intended, "good" quality might include a range of quality that is less than perfect.

10.3 Sampling Risks. In the foregoing it has been indicated that there are certain risks inherent to inspection. In the case of sampling inspection, there is, in addition to the error in human performance, a special kind of risk that can be attributed to the "luck of the draw" that results in erroneous decisions relative to "good" and "bad" lots. In other words, whenever sampling is involved there is always the risk (or chance) that good lots may be rejected and bad lots accepted. In general, the smaller the sample size, the greater the risk of selecting a sample which does not truly reflect the quality of its parent lot and of making an erroneous accept/reject decision. Since risks are inherent to sampling plans, this relationship should be clearly understood. The problem of these risks may be restated as follows: "Assuming that a lot is some given percent defective, what is the chance (probability) that the lot will be accepted or rejected by the sampling plan?" When the given percent defective is in the region of good quality, both supplier and consumer will be interested in a high probability of lot acceptance, and when the given percent defective is in the region of bad quality, the consumer especially will be interested in a high chance that the lot will be rejected. These probabilities of acceptance and rejection can be determined from the performance curve, or operating characteristic curve, of the sampling plan. The curve shown in Figure 1 for the single sampling plan indicates the chance of lots of varying quality (percent defective) being accepted. Due to chance variations, samples drawn from lots of identical quality may themselves be very unequal in quality and thus yield very different test results. Some of the test results may be so far from correctly reflecting the quality of the parent lot that the parent lot is either incorrectly rejected (if lot quality is good) or incorrectly accepted (if lot quality is bad). The probability that a sampling plan leads to the rejection of a good lot is called the producer's or "alpha" risk. The probability that a sampling plan leads to the acceptance of a bad lot is called the consumer's or "beta" risk.

10.4 Operating Characteristic (OC) Curves. The protection afforded by a sampling plan, that is, its capability to discriminate between good and bad quality can be accurately calculated. The fact that these risks can be quantified makes it possible to state these risks statistically (numerically) and predict the quantities rejected on the average over the entire possible range of product quality. Such calculations - based on the mathematical theory of probability - provide the basis for the curve shown in Figure 1. The curve of Figure 1 indicates the relationship between the quality of lots submitted for inspection and the probability of acceptance and is identified as the plan's operating characteristic curve, or OC curve. OC curves are a graphical means for showing the relationship between quality of lots submitted for sampling inspection (usually expressed in percent defective, but may also be expressed in defects per hundred units) and the probability that the sampling plan will yield a decision to accept the lot (described as the "probability of acceptance"). In preparing the OC curve, the percent defective of submitted lots is generally shown graphically on the horizontal scale, ranging from zero to some conveniently selected value of percent defective (not exceeding 100%) or defects per hundred units representing less than perfect quality. Along the vertical scale of the graph, the percent (or fraction) of lots that may be expected to be accepted by the particular sampling plan are shown - also ranging from zero to 100% (zero to 1, if the scale is in fraction of lots). Obviously, lots which contain zero percent defective will be accepted 100% of the time by any sampling plan, and lots which are 100% defective will never be accepted; consequently, the initial and terminal points (highest and lowest) on the graph can be plotted without the need for calculation. The points in between follow a smooth curve and are obtained from mathematical probability computation. Appendix B in this handbook as well as textbooks on statistical quality control and related procedures (see Appendix A) describe the exact procedures for constructing OC curves.

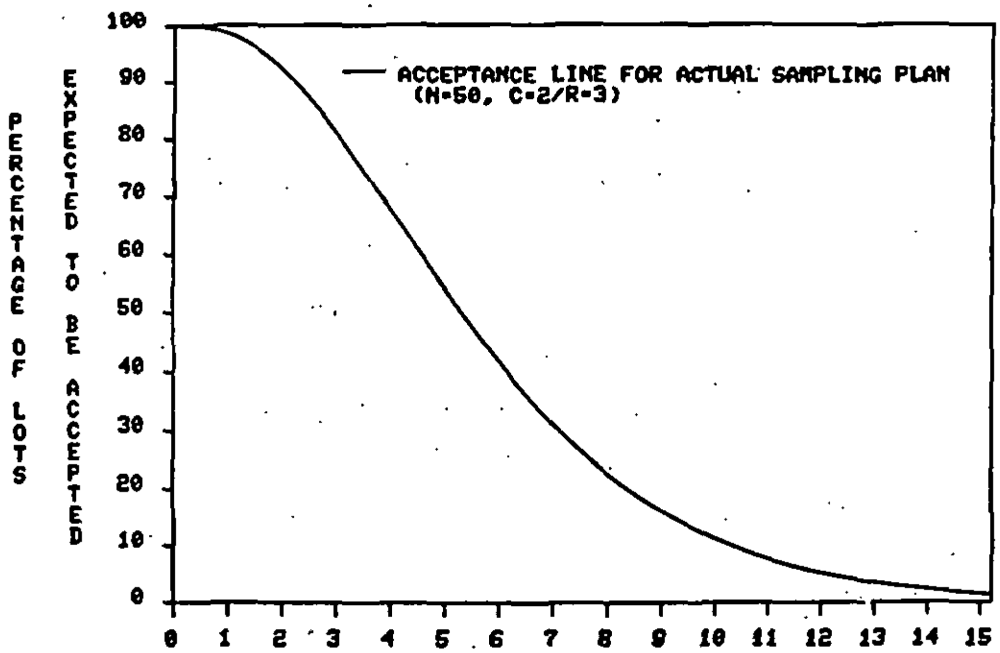

FIGURE 1. A THEORETICAL SAMPLING PLAN

10.4.1 Selecting the Sampling Plan. Two factors are generally considered in the selection of a sampling plan: (1) the consumer and/or supplier risk factor and (2) the economic factor. The risk pattern of each sampling plan is represented by the OC curve for the plan. The OC curve for each plan is different, a property which provides an effective means for ascertaining the effect of changes in sample size and acceptance number on the acceptance or rejection of a lot. The proper (with respect to risk) sampling plan can be determined from studying the OC curve for each plan under consideration. By studying the OC curves, it is possible to compare the relative risks of two or more sampling plans for a given sampling situation. By virtue of the OC curve, sampling tables can be constructed in which risks of incorrect decisions have been determined in advance, making it possible to select plans which will have risk factors that are acceptable to both the supplier and the consumer. The OC curve, then, can be used for classifying sampling plans from the standpoint of the protection afforded to the supplier (AQL plans), consumer (LQ plans), or both. The economic factor must be considered each time a sampling plan is to be selected and, of course, becomes more and more important as the cost of testing goes up. This factor becomes especially important when, because of the high cost of testing, sample size must be limited to a degree which forces a compromise of the risk requirements specified for the sampling plan. Another approach to selecting sampling plans is used by some organizations which handle many types of items. Instead of selecting a sampling plan on an item by item basis as the above procedure suggests, a standard operating procedure is established whereby a particular very stringent sampling plan (probably acceptance number of zero and large sample size, perhaps the entire population) is designated to use when inspecting any quality characteristic that may be a critical defect, a second but less stringent sampling plan is designated to use when inspecting any quality characteristic or group of quality characteristics that will be at worst a major defect(s), and a third and still less stringent sampling plan is designated to use when inspecting any quality characteristic or group of quality characteristics that will be no worse than a minor defect(s).

10.4.2 Effects of Changes to the Sampling Plan on the OC Curve. A sampling plan and its associated risks are completely defined by the lot size, sample size, and acceptance number. The lot size, except in the case of very small lots, has relatively little importance in most cases in determining the risks associated with any given sampling plan. Thus, sample sizes and acceptance numbers are the two important factors which influence the risk pattern of sampling plans. If the risks of a tentative sampling plan are considered unsatisfactory, the question which follows is: "What changes must be made to obtain the desired sampling protection?" This can be answered by considering the effect on the OC curve of changes in the sampling plan. To understand the effect of such changes, a more detailed study of the OC curve (see Figure 2) is appropriate. From examination of this curve it is seen that if lots to be inspected are 2% defective, approximately 90% of the lots are expected to be accepted, whereas if the lots submitted are 8% defective, about 10% of the lots are expected to be accepted. If 2% defective and 8% defective represent good and bad quality lots, respectively, the good lots will be rejected 10% (100 - 90 = 10) of the time (producer's risk) and bad lots accepted but 10% of the time (consumer's risk). This rejection/acceptance frequency will occur by chance. If this frequency is intolerable, appropriate changes to the sampling plan are required.

10.4.3 Changes in Sample Size. An increase in sample size results in a steepening of the OC curve, as indicated in Figure 3. The steeper the OC curve, the greater the power of the sampling plan to discriminate between "good" and "bad" quality. Figure 3 clearly illustrates the effect that increasing sample size has on making the OC curve "steeper".

10.4.4 Changes in Acceptance Number. Figure 4 illustrates the effect of changes in the acceptance/rejection numbers on the OC curve. In general, the effect of increasing the acceptance number is to shift the location of the entire OC curve to the right. Changing the sampling plan in this way generally increases the probability of accepting a lot at a given quality level.

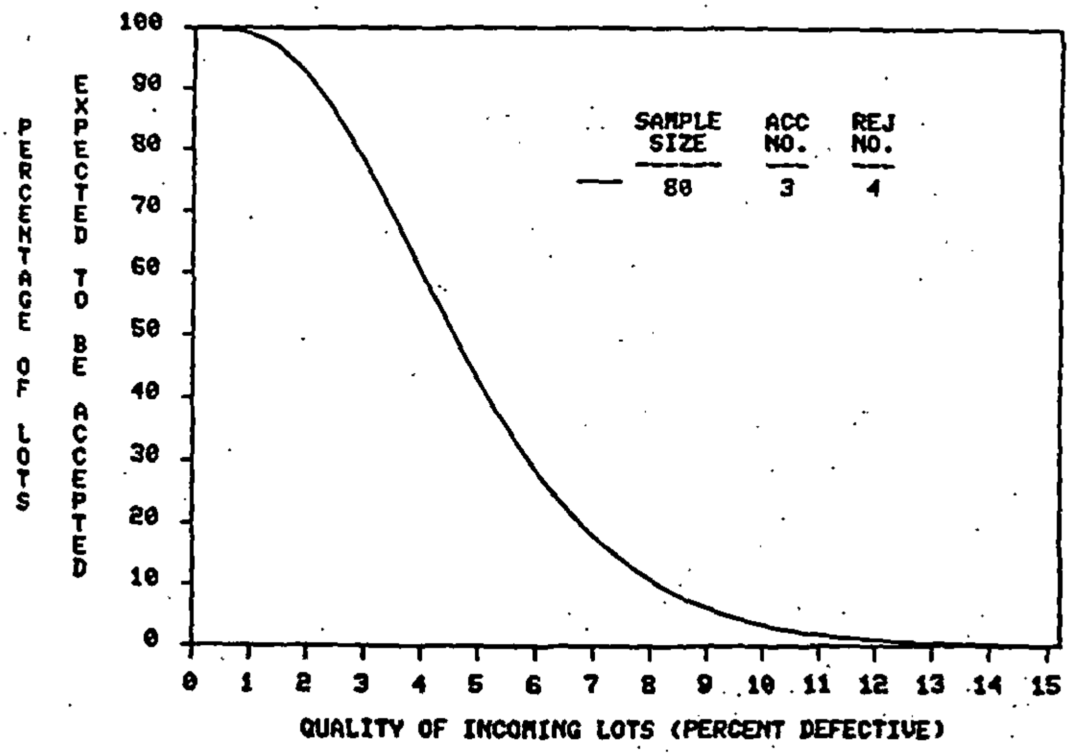

FIGURE 2. O.C. CURVE FOR A TYPICAL SAMPLING PLAN

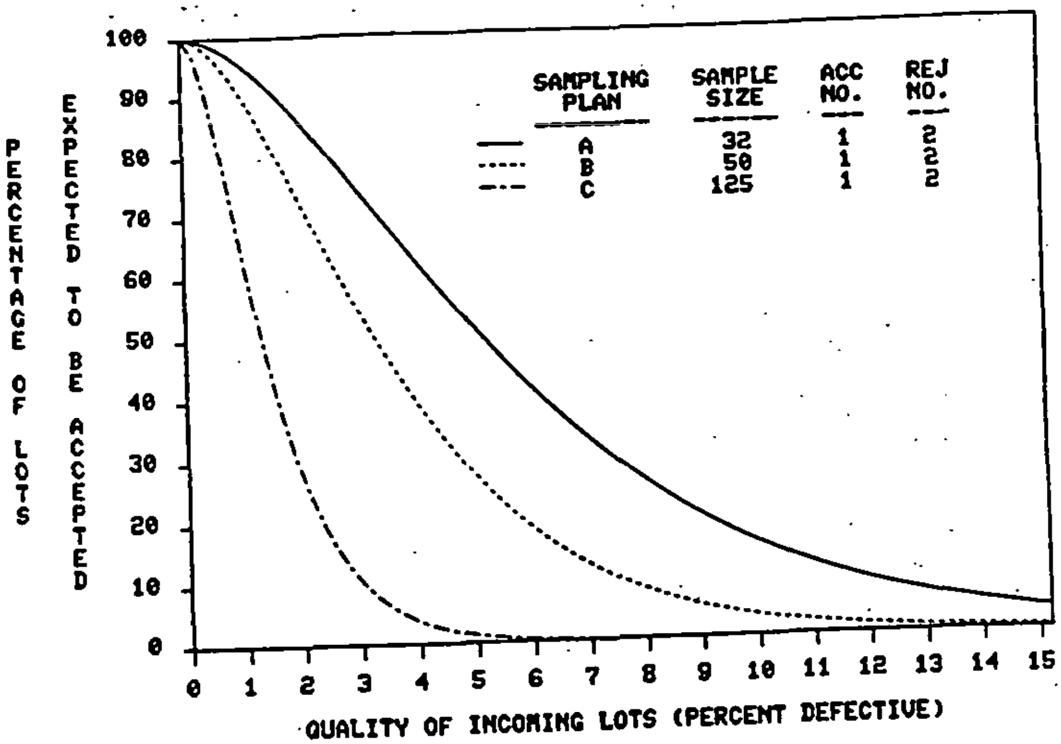

FIGURE 3. EFFECT OF CHANGING SAMPLE SIZE ON OC CURVE

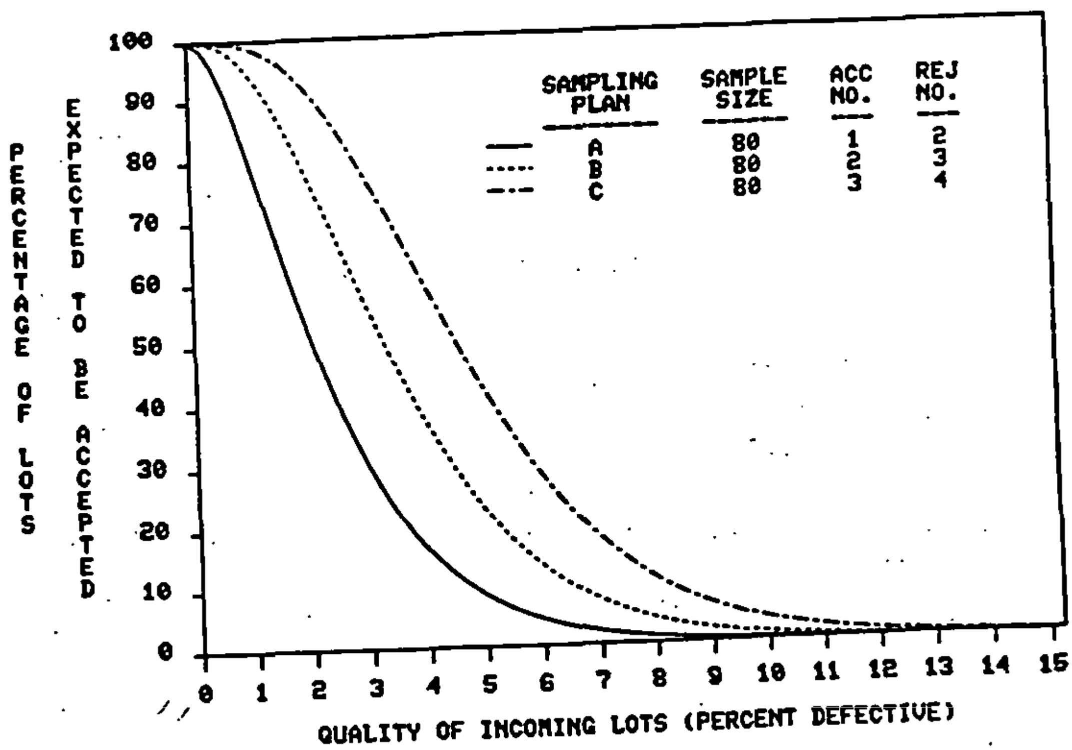

FIGURE 4. EFFECT OF CHANGING ACCEPTANCE NUMBER ON OC CURVE

10.4.5 Simultaneous Change of Sample Size and Acceptance Number. If it is desired to have more accurate disposition of the lots whose percent defective is close to the selected quality level (the AQL or the LQ for example), the sample size must be increased to provide more discrimination. Also, the acceptance number must be selected which will yield the OC curve that is properly located about the "desired" quality level. Thus, if the degree of discrimination of a given plan is considered adequate, but the probability of accepting a lot at a given quality level is too great (i.e., the plan is "too loose") or too small (i.e., the plan is "too tight"), proper adjustment is made by selecting the appropriate acceptance number. Usually in practice, if a sampling plan is desired which has certain desirable risk characteristics, both sample size and acceptance numbers must be simultaneously adjusted (See Figure 5). In order to make proper adjustment, however, the effect of each must be understood.

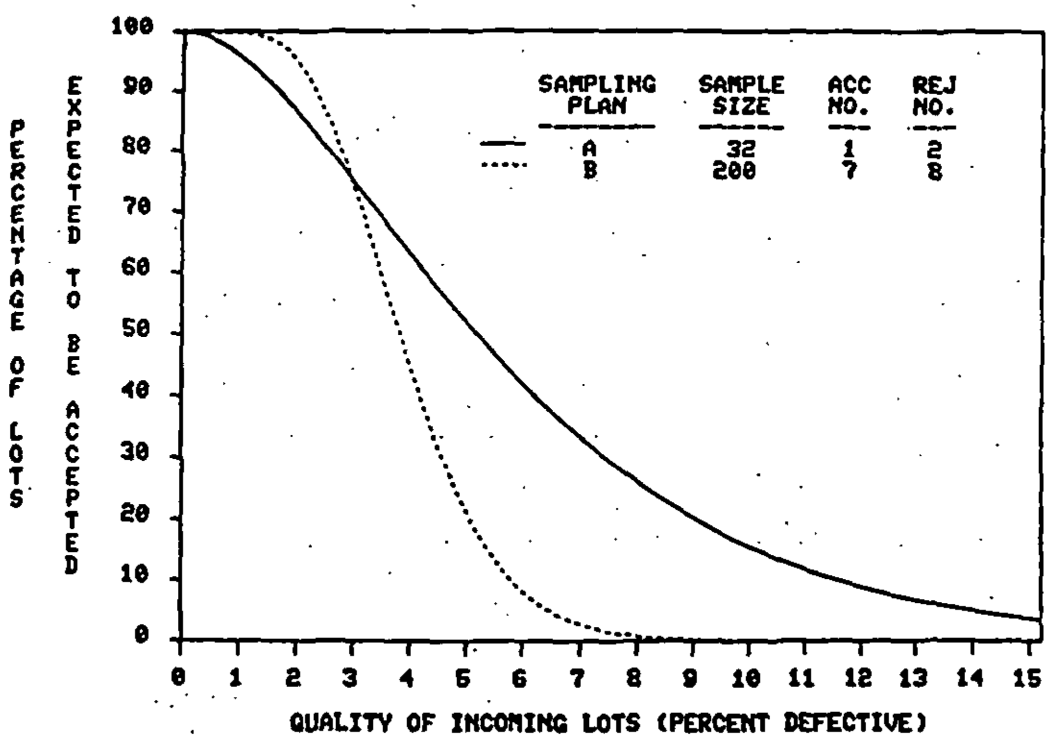

FIGURE 5. EFFECT OF SIMULTANEOUS CHANGE OF SAMPLE SIZE AND ACCEPTANCE NUMBER ON O.C. CURVE

10.4.6 OC Curves as a Basis for Selecting Sampling Plans. As indicated earlier, one of the advantages of sampling inspection, in which mathematically developed sampling plans are used, is that one can determine the probability of accepting a lot at all points on the process average scale. From the preceding paragraphs, it should be apparent that the probability or likelihood of accepting a lot under a particular sampling plan is completely described by the OC curve for that sampling plan. By study of the OC curves, therefore, it is possible to compare the relative effectiveness of two or more sampling plans for use in a given situation, or to construct special tables in which the risks of incorrect decisions have been rationally determined. In a particular situation, the desired degree of discrimination may result in a large sample size being required, but if destructive or very expensive testing is involved, it may be uneconomical to inspect such a large percentage of the lot, so that a compromise must be reached. In reality, this kind of compromise is reached every time a decision to use a sampling inspection plan is made. The consumer would naturally prefer perfect quality. However, any attempt to guarantee perfection would require 100% (or perhaps 200% or 300%) inspection. For characteristics resulting in hazardous conditions, this may be warranted and necessary. For others, a certain amount of non-perfection is usually satisfactory, and the actual decision then becomes one of balancing the cost of inspection against the cost of defectiveness which might be accepted by the sampling procedure. In view of this fact, therefore, it should be apparent that administrators (and inspectors who must select their own sampling plans) should familiarize themselves with the basis for interpreting OC curves. Both MIL-STD-105 and MIL-STD-414 contain OC curves for each sampling plan (i.e., sample size and acceptance-rejection criterion) listed. Also, this handbook contains OC curves for sampling schemes in MIL-STD-105 (see Section 26 and Appendix C).

SECTION 11: SEVERITY OF INSPECTION

11.1 General. The severity of inspection is reflected by the total amount of inspection and the accept/reject criterion specified by the quality assurance provisions established for the unit of product, or as dictated by quality history. Properly done, lot sampling inspection provides for two or three degrees of severity of inspection: (1) normal and tightened, or (2) normal, tightened, and reduced. These degrees of severity are applied in both attributes and variables sampling inspection plans. When sampling plans of two or three (or more) degrees of severity are used to inspect lots of product, these plans together with the rules for switching from one degree of severity to another are called a sampling scheme.

11.2 Normal Inspection. Normal inspection is that which is used when there is no evidence that the quality of product being submitted is better or poorer than the specified quality level. Normal inspection is usually used at the start of inspection and is continued as long as there is evidence that the product quality is consistent with specified requirements. Tightened inspection is instituted in accordance with established procedures when it becomes evident that product quality is deteriorating. Reduced inspection may be instituted in accordance with established procedures when it is evident that product quality is very good.

11.3 Tightened Inspection. Tightened inspection under a sampling scheme requires a more stringent acceptance criterion than does the normal inspection plan with which it is used. This requirement is usually met by decreasing the number of defectives or defects per hundred units produced in the sample. The effect of this decrease is generally to increase the producer's risk while reducing the consumer's risk (See 10.3.4 and Figure 4). When it is evident that product quality has improved, normal inspection may be reinstituted.

11.4 Reduced Inspection. Reduced inspection normally requires a smaller sample size than does normal inspection under the same sampling scheme. The effect of this decrease in sample size is to slightly reduce the producer's risk while significantly increasing the consumer's risk. The requirements for switching from normal inspection to reduced inspection are usually much more involved than for switching from normal to tightened inspection. A proven quality history for the product is essential in deciding to switch from normal to reduced inspection. Switching from normal to tightened inspection is usually a mandatory requirement, but switching from normal to reduced inspection is permissive under certain conditions. When the product quality shows evidence of deterioration, switching from reduced to normal inspection is mandatory.

SECTION 12: SAMPLE SELECTION

12.1 General. Basic to sampling inspection is the selection of a sample which can be reasonably expected to represent the quality of the parent lot. Hence, the procedure used to select units from a lot must be such that it assures a sample free of bias. (That is, a random sampling procedure. See next paragraph.) The process of selecting a sample meeting this requirement is called random sampling.

12.2 Random Sampling. A sample consists of one or more units of product drawn from a lot or batch. Random sampling is any procedure used to draw units from an inspection lot so that each unit in the lot has an equal chance, without regard to its quality, of being included in the sample. A basic requirement of sampling inspection is that, over the long run, samples represent lot quality to a high degree. If the units in a lot have been thoroughly mixed, sorted, or arranged without bias as to their quality, a sample drawn anywhere from the lot will meet the requirements of randomness. Sometimes it is not practical to mix the units thoroughly because of their physical dimensions or for other reasons. Sometimes the best that can be done in drawing a sample is to avoid any type of obvious bias. For example, if the units are stacked in layers, bias could obviously result if the entire sample is drawn from only the top layer. It is possible to reduce bias by avoiding such pitfalls as drawing units from the same position in containers, stacks, or piles; selecting units from the output of one machine and not others; or selecting units which appear to be defective or nondefective. (See 14.2 for the proper way to handle obviously defective units of product observed in the population by an inspector.) If such biased sampling procedures are avoided, it will be easier to obtain a sample that approaches a random sample and will better reflect the overall quality of the lot.

12.2.1 Table of Random Numbers and Random Sampling. A table of random numbers is a set of digits that has been generated in such a way that: (1) each digit appears in approximately one tenth (if all ten digits are being used in the table) of the positions and (2) repeating patterns of digits are avoided. A table of random numbers, similar to Table A, may be used to draw a random sample of units from the lot. Each unit in the lot must be identified by a distinctly different number. This can often be done by placing the units in racks or trays where the rows and columns of positions in the racks are distinctly numbered. If the units have serial numbers, these serial numbers can be used. The three-dimensional position of each unit (row, column, depth) in a large grouping can also be used. A table of random numbers can then be used to select the random sample. If more extensive tables of random numbers are needed, the RAND Corporation's "A Million Random Digits with 100,000 Normal Deviates" (see Appendix A) or other suitable sources of random numbers may be used.

Example 2: Selecting Random Numbers. Assume a sample of five units is to be selected at random from an inspection lot containing fifty units numbered from 1 to 50. In order to select five random numbers from Table A, begin by letting a pencil fall blindly at some number in the table and start at this point. Toss a coin to decide which way to go: heads, go up; tails, go down. The randomness of numbers in Table A is preserved by any method of reading across, diagonally, up or down the columns. Suppose a pencil falls on column (5) and row (17). The decision is made to read down the column and take only the first two digits in each number of five digits. The selection of random numbers is made as follows: reject 89 since it it over 50, the lot size; take the random numbers 31, 23, 42, 09 and 47. The units numbered 9, 23, 31, 42 and 47 should be drawn from the lot to form a random sample of five units.

12.2.2 Additional Applications. The largest number in a random number table should be at least as large as the number of units in the inspection lot. A table of two digit numbers (00 - 99) will be sufficient for lots having 100 or fewer units. A table of five digit numbers (Table A) will be sufficient for lots having 100,000 or fewer units. For larger lot sizes, Table A can still be used by ignoring the break between columns. For example, if a series of six digit random numbers is desired, the five digits of column (1) may be connected to the first digit of column (2); or the last four digits of column (1) may be connected to the first two digits of column (2); and so on.

TABLE A-1 TABLE OF RANDOM NUMBERS

Line \ Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	10480	15011	01536	02011	81647	01646	69179	14194	62590	36207	20969	99570	91291	90700
2	22368	46573	25595	85393	30995	89198	27982	53402	93965	34095	52666	19174	39615	99505
3	24130	48360	22527	97265	76393	64809	15179	24830	49340	32081	30680	19655	63348	58629
4	42167	93093	06243	61680	07856	16376	39440	53537	71341	57004	00849	74917	97758	16379
5	37570	39975	81837	16656	06121	91782	60468	81305	49684	60672	14110	06927	01263	54613
6	77921	06907	11008	42751	27756	53498	18602	70659	90655	15053	21916	81825	44394	42880
7	99562	72905	56420	69994	98872	31016	71194	18738	44013	48840	63213	21069	01634	12952
8	96301	91977	05463	07972	18876	20922	94595	56869	69014	60045	18425	84903	42508	32307
9	89579	14342	63661	10281	17453	18103	57740	84378	25331	12566	58678	44947	05585	56941
10	85475	36857	53342	53988	53060	59533	38867	62300	08158	17983	16439	11458	18593	64952
11	28918	69578	88231	33276	70997	79936	56865	05859	90106	31595	01547	85590	91610	78188
12	63553	40961	48235	03427	49626	69445	18663	72695	52180	20847	12234	90511	33703	90322
13	09429	93969	52636	92737	88974	33488	36320	17617	30015	08272	84115	27156	30613	74952
14	10365	61129	87529	85689	48237	52267	67689	93394	01511	26358	85104	20285	29975	89568
15	07119	97336	71048	08178	77233	13916	47564	81056	97735	85977	29372	74461	28551	90707
16	51085	12765	51821	51259	77452	16308	60756	92144	49442	53900	70960	63990	75601	40719
17	02368	21382	52404	60268	89368	19885	55322	44819	01188	65255	64835	44919	05944	55157
18	01011	54092	33362	94904	31273	04146	18594	29852	71585	85030	51132	01915	92747	64951
19	52162	53916	46369	58586	23216	14513	83149	98736	23495	64350	94738	17752	35156	35749
20	07056	97628	33787	09998	42698	06691	76988	13602	51851	46104	88916	19509	25625	58104
21	48663	91245	85828	14346	09172	30168	90229	04734	59193	22178	30421	61666	99904	32812
22	54164	58492	22421	74103	47070	25306	76468	26384	58151	06646	21524	15227	96909	44592
23	32639	32363	05597	24200	13363	38005	94342	28728	35806	06912	17012	64161	18296	22851
24	29334	27001	87637	87308	58731	00256	45834	15398	46557	41135	10367	07684	36188	18510
25	02488	33062	28834	07351	19731	92420	60952	61280	50001	67658	32586	86679	50720	94953
26	81525	72295	04839	96423	24878	82651	66566	14778	76797	14780	13300	87074	79666	95725
27	29676	20591	68086	26432	46901	20849	89768	81536	86645	12659	92259	57102	80428	25280
28	00742	57392	39064	66432	84673	40027	32832	61362	98947	96067	64760	64584	96096	98253
29	05366	04213	25669	26422	44407	44048	37937	63904	45766	66134	75470	66520	34693	90449
30	91921	26418	64117	94305	26766	25940	39972	22209	71500	64568	91402	42416	07844	69618
31	00582	04711	87917	77341	42206	35126	74087	99547	81817	42607	43808	76655	62028	76630
32	00725	69884	62797	56170	86324	88072	76222	36086	84637	93161	75038	65855	77919	88006
33	69011	65795	95876	55293	18988	27354	26575	08625	40801	59920	29841	80150	12777	48501
34	25976	57948	29888	88604	67917	48708	18912	82271	65424	69774	33611	54262	85963	03547
35	09763	83473	73577	12908	30883	18317	28290	35797	05998	41688	34952	37888	38917	88050
36	91567	42595	27958	30134	04024	86385	29880	99730	55536	84855	29080	09250	79656	73211
37	17955	56349	90999	49127	20044	59931	06115	20542	18059	02008	73708	83517	36103	42791
38	46503	18584	18845	49618	02304	51038	20655	58727	28168	15475	56942	53389	20562	87338
39	92157	89634	94824	78171	84610	82834	09922	25417	44137	48413	25555	21246	35509	20468
40	14577	62765	35605	81263	39667	47358	56873	56307	61607	49518	89656	20103	77490	18062
41	98427	07523	33362	64270	01638	92477	66969	98420	04880	45585	46565	04102	46880	45709
42	34914	63976	88720	82765	34476	17032	87589	40836	32427	70002	70663	88863	77775	69348
43	70060	28277	39475	46473	23219	53416	94970	25832	69975	94884	19661	72828	00102	66794
44	53976	54914	06990	67245	68350	82948	11398	42878	80287	88267	47363	46634	06511	97809
45	76072	29515	40980	07391	58745	25774	22987	80059	39911	96189	41151	14222	60697	59583
46	90725	52210	83974	29992	65831	38857	50490	83765	55657	14361	31720	57375	56228	41546
47	64364	67412	33339	31926	14883	24413	59744	92351	97473	89286	35931	04110	23726	51900
48	08962	00358	31662	25388	61642	34072	81249	35648	56891	69352	48373	45578	78547	81788

TABLE A: TABLE OF RANDOM NUMBERS (Continued)

49	95012	68379	93526	70765	10592	04542	76463	54328	02349	17247	28865	14777	62730	92277
50	15664	10493	20492	38391	91132	21999	59516	81652	27195	48223	46751	22923	32261	85653
51	16408	81899	04153	53381	79401	21438	83035	92350	36693	31238	59649	91754	72772	02338
52	18629	81953	05520	91962	04739	13092	97662	24822	94730	06496	35090	04822	86774	98289
53	73115	35101	47498	87637	99016	71060	88824	71013	18735	20286	23153	72924	35165	43040
54	57491	16703	23167	49323	45021	33132	12544	41035	80780	45393	44812	12515	98931	91202
55	30405	83946	23792	14422	15059	45799	22716	19792	09983	74353	68668	30429	70735	25499
56	16631	35006	85900	98275	32388	52390	16815	69298	82732	38480	73817	32523	41961	44437
57	96773	20206	42559	78985	05300	22164	24369	54224	35083	19687	11052	91491	60383	19746
58	38935	64202	14349	82674	66523	44133	00697	35552	35970	19124	63318	29686	03387	59846
59	31624	76384	17403	53363	44167	64486	64758	75366	76554	31601	12614	33072	60332	92325
60	78919	19474	23632	27889	47914	02584	37680	20801	72152	39339	34806	08930	85001	87820
61	03931	33309	57047	74211	63445	17361	62825	39908	05607	91284	68833	25570	38818	46920
62	74426	33278	43972	10119	89917	15665	52872	73823	73144	88662	88970	74492	51805	99278
63	09066	00903	20795	95452	92648	45454	09552	88815	16553	51125	79375	97596	16296	66092
64	42238	12426	87025	14267	20979	04508	64535	31355	86064	29472	47689	05974	52468	16834
65	16153	08002	26504	41744	81959	65642	74240	56302	00033	67107	77510	70625	28725	34191
66	21457	40742	29820	96783	29400	21840	15035	34537	33310	06116	95240	15957	16572	06004
67	21581	57802	02050	89728	17937	37621	47075	42080	97403	48626	68995	43805	33386	21597
68	55612	78095	83197	33732	05810	24813	86902	60397	16489	03264	88525	42786	05269	92532
69	44657	66999	99324	51281	84463	60563	79312	93454	68876	25471	93911	25650	12682	73572
70	91340	84979	46949	81973	37949	61023	43997	15263	80644	43942	89203	71795	99533	50501
71	91227	21199	31935	27022	84067	05462	35216	14486	29891	68607	41867	14951	91696	85065
72	50001	38140	66321	19924	72163	09538	12151	06878	91903	18749	34405	56087	82790	70925
73	65390	05224	72958	28609	81406	39147	25549	48542	42627	45233	57202	94617	23772	07896
74	27504	96131	83944	41575	10573	08619	64482	73923	36152	05184	94142	25299	84387	34925
75	37169	94851	39117	89632	00959	16487	65536	49071	39782	17095	02330	73401	00275	48280
76	11508	70225	51111	38351	19444	66499	71945	05422	13442	78675	84081	66938	93654	59894
77	37449	30362	06694	54690	04052	53115	62757	95348	78662	11163	81651	50245	34971	52924
78	46515	70331	85922	38329	57015	15765	97161	17869	45349	61796	66345	81073	49106	79860
79	30986	81223	42416	58353	21532	30502	32305	86482	05174	07901	54339	58861	74818	46942
80	63798	64995	46583	09785	44160	78128	83991	42865	92520	83531	80377	35909	81250	54238
81	82486	84846	99254	67632	43218	50076	21361	64816	51202	88124	41870	52689	51275	83556
82	21885	32906	92431	09060	64297	51674	64126	62570	26123	05155	59194	52799	28225	85762
83	60336	98782	07408	53458	13564	59089	26445	29789	85205	41001	12535	12133	14645	23541
84	43937	46891	24010	25560	86355	33941	25786	54990	71899	15475	95434	98227	21824	19585
85	97656	63175	89303	16275	07100	92063	21942	18611	47348	20203	18534	03862	78095	50136
86	03299	01221	05418	38982	55758	92237	26759	86367	21216	98442	08303	56613	91511	75928
87	79626	06486	03574	17668	07785	76020	79924	25651	83325	88428	85076	72811	22717	50585
88	85636	68335	47539	03129	65651	11977	02510	26113	99447	68645	34327	15152	55230	93448
89	18039	14367	61337	06177	12143	46609	32989	74014	64708	00533	35398	58408	13261	47908
90	08362	15656	60627	36478	65648	16764	53412	09013	07832	41574	17639	82163	60859	75567
91	79556	29068	04142	16268	15387	12856	66227	38358	22478	73373	88732	09443	82558	05250
92	92608	82674	27072	32534	17075	27698	98204	63863	11951	34648	88022	56148	34925	57031
93	23982	25835	40055	67006	12293	02753	14827	23235	35071	99704	37543	11601	35503	85171
94	09915	96306	05908	97901	28395	14186	00821	80703	70426	75647	76310	88717	37890	40129
95	59037	33300	26695	62247	69927	76123	50842	43834	86654	70959	79725	93872	28117	19233
96	42488	78077	69882	61657	34136	79180	97526	43092	04098	73571	80799	76536	71255	64239
97	46764	86273	63003	93017	31204	36692	40202	35275	57306	55543	53203	18098	47625	88684
98	03237	45430	55417	63282	90816	17349	88298	90183	36600	78406	06216	95787	42579	90730
99	86591	81482	52667	61582	14972	90053	89534	76036	49199	43716	97548	04379	46370	28672
100	38534	01715	94964	87288	65680	43772	39560	12918	86537	62738	19636	51132	25739	56947

12.2.3 Alternated Methods. A list of numbers that are at least nearly random can be constructed if a random number table is not available. Some possible ways of constructing such a list follow.

a. Remove all jokers and face cards (jacks, queens, kings) from a deck of regular playing cards. Let the 10 count as a zero and the ace count as a 1. Shuffle the remaining deck of 40 cards thoroughly and cut the deck as in playing bridge or poker. Turn over the top card and record its number. Return the card to the deck, shuffle and cut the deck, and again draw the top card and record its number. Continue this process until a "random" number table of sufficient length is constructed. If a list of two digit numbers is needed, let the first card drawn be the first digit of the first number and the second card drawn be the second digit of the first number; let the third card drawn be the first digit of the second number and the fourth card be the second digit of the second number; and so on. This method can, of course, be used to construct a list with numbers as many digits in length as is needed for a particular task, or it can be used to construct a table of numbers for general use, similar to Table A. It must be emphasized that in using this method, (1) each card drawn must be reinserted in the deck, and (2) the deck shuffled before the next draw. Failure to carry out these two steps before each card draw will significantly reduce the randomness of the number list.

b. A series of one digit numbers that are "somewhat" random can be generated by using, in the following way, the page numbers of a book containing more than three hundred pages.

1. Open the book at a strictly arbitrary point.
2. Note the two page numbers, one odd and one even.
3. Select the odd or even numbered page by flipping a coin.
4. Record the last digit of the selected page.

Caution must be used if the pages tend to part at the same number more frequently than appears logical for producing random numbers, such as when the binding of the book has been broken at a specific page number. These one digit numbers can be accumulated in pairs, threes, and so on, to develop two, three, and larger digit "random" numbers. The use of random number tables is preferred, but this method can be used with proper precautions.

12.3 Constant Interval Sampling. When units of product are arranged in an order without regard to their quality (such as data records on magnetic tapes or product units in a tray), the sample may be drawn by using a constant interval technique. By this method, a constant interval is maintained between the units drawn for the sample. Thus every 8th, 17th or 23rd unit of a consecutively ordered lot may be selected. The first unit to be drawn from the lot may be determined from a table of random numbers. All other units in the sample are drawn at a constant interval following the first unit. The amount of the constant interval is determined by dividing the lot size by the sample size. A danger in using this sampling technique is that the characteristic for which inspection is to be done may vary in some periodic fashion that coincides with the length of the sampling interval. In such a situation, the sample would not truly represent the population, and inspection results could mislead an observer about the quality of the population. Hence, constant interval sampling is one of the less desirable sampling methods, and caution should be exercised in its use.

Example 3: <u>Constant Interval Sampling</u>. Assume the lot size is 20,000 units and a sample of 315 units is to be drawn. The constant interval is computed by dividing the lot size by the sample size:

$$20{,}000 \div 315 = 63$$

The first step is to select a random number from 1 to 63 from a table of random numbers or by other appropriate methods. After the first unit has been drawn, the remaining units in the required sample size are drawn by selecting every 63rd unit from the lot until the total sample size of 315 is reached.

12.4 <u>Stratified Sampling</u>. Under certain conditions it may be necessary to divide the lot into sublots so that information can be obtained about specific parts or strata of the lot. The division of the lot into stratified sublots requires considerable knowledge and judgement concerning the characteristics of the product. A sample is drawn from each sublot as though it were an independent lot. Statistical decisions regarding the acceptance or rejection of the product quality can be made for each sublot.

Example 4: <u>Stratified Sampling</u>. Assume the lot consists of 38,100 units produced from five different machines (or operators) and sampling inspection is used to determine the acceptance or rejection of product for each machine (or operator). The sublot sizes for each machine (or operator) and related sample sizes may be as follows:

Machine Number	Sublot Size	Sample Size
1	30,000	315
2	4,000	200
3	3,000	125
4	1,000	80
5	100	20
TOTAL:	38,100	740

Although the acceptance or rejection of the entire lot (38,100 units) might have been determined from a single sample of 500 units drawn at random from the entire lot, much more information is obtained by forming sublots (one for each machine or operator) and accepting or rejecting the product of each machine or operator. Thus particular machines or operators can be identified as producing acceptable or rejectable quality products. While this example is presented to illustrate stratified sampling, another point may be made regarding the homogeneity of product within a lot. In those cases where lot homogeneity is an especially sensitive problem, it may be required to perform a statistical comparison test to confirm that the several machines or production lines are manufacturing homogeneous product. If tests are negative and it is otherwise feasible, product from the several machines/production lines may be formed into more than one lot instead of a single lot. (See also 6.4.)

12.5 Sampling from an Unlabeled Population. In some circumstances a unit of product may be more easily selected for a sample as it moves along its production line (perhaps as it passes a sampling or inspection station) rather than after it has been accumulated into a lot. During periods of one hundred percent sampling, the sampler (possibly an inspector) needs no device for selecting a sample. However, if only a fraction, f, of the product is to be included in the sample, then some selection device (preferably random) is needed. Any one of a number of devices may be used, several of which will be discussed here. The first device discussed is a random number table. The devices discussed after that are either commonly available, easily obtained, or easily constructed.

a. Random Number Tables. A random number table may be used to select a fraction, f, of the units of product as they come to the sampling station. As before, when using a random number table, select a starting point and a direction to move in the table to select successive numbers (para. 12.2.1, Example 2). Write the sampling fraction, f, as a decimal. For example, if $f = 1/7$, express it as $f = 1 \div 7 = .14285$ ----. This fraction may be rounded to as many places as desired.

If $f = 1/7$ were rounded to two places we would have $f = .14$. Expressing f as a decimal instead of a fraction changes the sampling rule slightly: instead of selecting one out of every seven units of product, on the average, select fourteen out of every one hundred units. As the first unit of product comes to the sampling station, determine the first two digit random number (the starting point selected above). If that number is 01 to 14, select the unit of product for the sample. If that number is 15 to 99 or 00, do not select the unit of product for the sample, but let it continue on the production line. Read the next two digit number in the random number table and using the same selection rule that was used for the first unit, select or do not select the next unit of product for the sample. Subsequent units of product are dealt with in the same way.

The method of sample selection is now illustrated using the random numbers in Table A. Suppose that a starting place is picked in Table A at column four, line ten and that, with the flip of a coin, the choice is made to move down in Table A to find successive random numbers. The following list shows the first ten two-digit numbers that would be taken from the table and what those numbers would have to say about selecting the first ten units of product.

Unit of Product No.	Table A Number	Disposition of Unit of Product
1	53	Do not select
2	33	Do not select
3	03	Select
4	92	Do not select
5	85	Do not select
6	08	Select
7	51	Do not select
8	60	Do not select
9	94	Do not select
10	58	Do not select

b. Coins. One or more coins offer a simple, readily available means of randomly selecting each unit of product as it appears at the sampling station. Coins may be used as indicated in the following table when it is desired to select a unit of product with the probability shown in the first column. This probability is also the fraction of units that, over the long run, will be selected for the sample. The second column shows the number of coins necessary to select a unit of product with the probability shown in the first column. The third column shows the number of heads (H) and tails (T) that must turn up when tossing the coins in order for the unit to be not selected. The fourth column shows the number of heads and tails that must turn up in order for the unit to be not selected. Of course the table could be continued for more than the four coins that are shown here. However, an increasing number of coins becomes increasingly complicated to handle, and, as will be seen below, other, less complicated methods are available.

Probability of Selecting Unit of Product	Number Coins	No. Heads (H) and Tails (T) to Select Unit of Product	No. Heads (H) and Tails (T) to Not Select Unit of Product
1/ 2 = .5	1	(1H, 0T)	(0H, 1T)
1/ 4 = .25	2	(2H, 0T)	(1H, 1T) or (0H, 2T)
1/ 8 = .125	3	(3H, 0T)	All others
3/ 8 = .375		(2H, 1T)	All others
1/16 = .0625	4	(4H, 0T)	All others
5/16 = .3125		(4H, 0T) or (3H, 1T)	All others
7/16 = .4375		(4H, 0T) or (2H, 2T)	All others

For example, if a sampler must randomly select units of product with a long run frequency of 3/8, he could, according to the above table, use three coins to make his selection. Any time three coin tosses turned up two heads and one tail in any order (HHT, HTH, or THH), the sampler would include the unit of product in the sample. If any other combination of heads and tails appeared, he would not include the unit of product in the sample.

c. Dice. Dice may be used as shown in the following table to select units of product that are presented to a sampler. The first column in the table shows the fraction of product to be selected from the production line over the long run. This fraction is also the probability of selecting each unit of product if the prescribed procedure is followed. Column 2 shows the number of dice to be used in carrying out the procedure on that line of the table. Column 3 shows the number of spots that are to appear on the dice if the unit of product is to be included in the sample. Column 4 shows the number of spots that are to appear if the unit of product is not to be included in the sample. Column 5 shows the number of spots that are to appear if the dice are to be rolled again. In other words, if a number appearing in Column 5 is rolled, no decision is made about selecting the unit of product at the sampling station. Instead, the dice are to be rolled again until a number turns up which appears in either column 3 or column 4.

Probability of Selecting Unit	No. Dice	No. of Spots Showing to Make Selection	No. of Spots Showing to Make Nonselection	No. of Spots Showing to Roll Again
1/36	2	2	All other	-
1/25	2	2	5 - 9	3,4,10-12
1/18	2	2,12	All other	-
1/15	2	3	2, 4-9	10 - 12
1/10	2	2,3	4-9	10 - 12
1/7	2	3,4	5-12	2
1/6	1	1	2-6	-
1/5	1	1	2-5	6
1/4	1	1	2-4	5,6
1/3	1	1,2	3-6	-
1/2	1	1-3	4-6	-
2/3	1	1-4	5,6	-
3/4	1	1-3	4	5,6

For example, if it is desired to sample at a frequency of 1/10, then two dice will be needed. If a roll of the dice turns up a three, say, (one die shows a single spot and the other shows two spots) then the unit of product is selected for the sample. If a five, say, is rolled, the unit of product is not included in the sample since the rule is that if any number of spots, 4 through 9 is rolled, the unit is not selected. If an eleven is rolled, no decision is made on selecting the unit of product for the sample. Instead, the dice are rolled again until some number from two to nine is rolled.

d. Colored beads in a jar. This method of random selection requires (1) some type of opaque container with a mouth wide enough that beads can be selected from within the jar, and (2) a number of beads of uniform shape, size, and texture. Each bead must be one of two colors, say red or green. The total number of beads in the jar is determined by the desired sampling frequency. For example, if one out of twenty-five units is to be selected, then the jar should contain twenty-five beads, one red and twenty-four green. If the selection ratio is to be three out of eleven, then the jar should contain eleven beads, three red and eight green. In order to determine if a unit of product is to be selected for the sample as it appears at the sampling station, the beads in the jar should first be thoroughly mixed and a single bead selected by a person who cannot see inside the jar. If, in either of the above two examples, the bead is red, then the unit of product is selected for the sample. If the bead is green, the unit is not selected. The bead is then returned to the jar and the beads in the jar are thoroughly mixed in preparation for the next bead selection.

e. Numbered discs. Numbers can be painted or pasted on plastic or paper discs, and the discs placed in an opaque jar. As with the beads in d, the discs must be undistinguishable to the touch. In order to select a disc, the jar is thoroughly mixed, and one of the discs selected by a person who cannot see inside the jar. The number on the disc is noted and a sample selection made accordingly. The disc is returned to the jar, and the discs in the jar are mixed in preparation for selection of the next disc. The method described here may be used in the following way to sample from a flow of units of product that is moving too fast to permit a convenient select/do not select decision on each product. If the product is to be sampled at frequency f, place in a jar 2/f discs numbered from 1 to 2/f. For example, if the flow of product is to be sampled at a rate of $f = 1/50$, place $2/f = 2 \div (1/50) = 100$ discs numbered from 1 to 100 in the jar. Just before the flow of product begins, mix the discs in the jar, randomly select a disc, note the number, i. Return the disc to the jar and thoroughly mix the discs again. As the flow of product begins, count the number of units passing the sampling station and select the ith unit of product for the sample. Shortly before this unit of product reaches the sampling station, select another numbered disc, note its number, j, return the disc to the jar, and again mix the jar of discs. Count the number of units that pass the sampling station after the ith unit, and select for the sample the unit receiving the jth count. Returning to the example in which the sampling rate is f=1/50 and discs numbered from 1 to 100 are placed in the jar, suppose that the number selected from the jar at the beginning of production is i = 67. The number is noted, the disc is returned to the jar, and all the discs are thoroughly mixed for the next disc selection. In the meantime, units of product are counted as they pass the sampling station, and the 67th unit is removed from the line for inspection. A second disc is selected just prior to the arrival of the 67th unit at the sampling station, and the number on it is j = 15. Thus, after the 67th unit has been removed from the line, the count to determine the fifteenth unit following is begun. This method of sampling selection may be continued indefinitely. This sample selection method is truly random so long as the numbered discs in the jar remain indistinguishable to the touch and are thoroughly mixed after each disc is returned. One drawback to this method in some situations may be the wide variation in the number of units between successive sample selections (from 1 to 2/f). In situations where this is the case and where the selection of a completely random sample is not mandatory, the method may be modified by limiting the numbers on the discs to some reduced range centered around 1/f. In the example with f = 1/50, the numbers placed in the jar might run only from 40 to 60. With 50 at the middle of this range of numbers, the long range sampling frequency would be f = 1/50. It must be remembered that reducing the range of numbers in this way also reduces the randomness of the selection method. Reducing the randomness somewhat probably causes no problem in most cases, especially if the production process is in control. However, reducing the range too much may introduce hazards such as those mentioned in connection with the constant interval sampling method in 12.3.

f. Arbitrary Selection. In some cases, perhaps because units of product move with such great speed or in such great volume along the production line, it may be impractical to select a sample by a random selection method. In such cases it may be necessary to select the sample by having the sampler simply reach into the flow of product and arbitrarily pick out a unit(s) of product. Although this method is quick and easy, it does have disadvantages and may cause problems, most of which arise because the sampler is somehow biased in which sample he selects. For example, a producer's inspector may be tempted to select only product with no obvious defects while a customer's inspector who is observing may object and insist on including any product he sees with obvious defects. The result may be a disagreement on whether or not the product being inspected is acceptable. Problems such as those described in 12.3 may also arise if the sampler tends to sample in some regular pattern. However, if the volume and rate of product along the production line are truly great enough to justify sampling without benefit of some random sampling device, the sampler will probably not be sampling in a sufficiently rigid pattern to cause the introduction of sampling bias. Hence, where the situation genuinely calls for it, samples may be selected arbitrarily. But because of the disadvantages, selecting samples in this way should be considered another "last resort" method.

SECTION 13: CURTAILMENT OF INSPECTION

There may be a temptation to stop inspection at the stage when the results being obtained make the final results almost a foregone conclusion. For example, suppose single sampling is in use, the sample size is 80, with acceptance number 10, rejection number 11, and in the first 50 of the sample only 2 defectives are found. It might be argued that having found only 2 in 50, it is not easily believable that another 9 or more will be found in the remaining 30, so why not accept at once and not bother to inspect the rest? This temptation must be resisted. It is true that it is not likely that 9 or more will be found in remaining 30, but it could happen and the plan must not be curtailed. Curtailment, then, is not permissible merely because a particular result seems probable, but it is permissible if, before the sample has been completely inspected, a particular result is certain (unless a record of the complete sample is required for some other reasons). For example, if the sample size is 80, acceptance number 10, rejection number 11, the finding of only three defectives in the first 73 sample units means acceptance even if all the remaining 7 units are defective, whereas the finding of 11 defectives in the first 20 sample units must mean rejection even if the remaining 60 sample units are all perfect. Whether inspection is curtailed in these circumstances depends upon administrative convenience, since to arrange for curtailment is sometimes more trouble than it is worth. Furthermore, if the sampling results are to be used to estimate process average quality, as well as to decide on acceptance and rejection, curtailment can lead to biased results and may be better avoided for this reason. In any case confusion and misunderstanding will be eliminated if a standard procedure is established that states clearly whether and under what circumstances inspection may be curtailed. See Section 34 of this handbook for curtailment of inspection when using MIL-STD-105.

SECTION 14: DISPOSITION OF DEFECTIVE PRODUCT

14.1 General. When conducting sampling inspection under a lot sampling plan, the entire lot is rejected if the acceptance criterion is not satisfied. The probability of rejecting lots of any given quality is shown by the OC curve for the sampling plan. The poorer the quality of lots submitted to the sampling plan, the greater the probability of rejection. The rejection of many lots introduces problems such as the disposition of the rejected lots, determination as to the remedial action to be taken, availability of storage space, rework time, disposition of scrap materials, difficulty in meeting delivery schedules as well as additional financial burden on the supplier. Failure of the supplier to correct the situation may even force a production stoppage, particularly when a large number of rejected lots are accumulated. Sometimes the consumer may agree to buy the rejected lot at a reduced price, especially when the product is in great demand and short supply. The more customary practice requires the rejected lots to be screened, defective units reworked or replaced, and the lot resubmitted by the supplier.

14.2 Obvious Defectives. Any sampling plan which requires less than 100% inspection of the product cannot guarantee that 100% of an accepted lot will be nondefective. This reality is reflected by AQLs for lot sampling plans having values greater than zero. However, the specification of a nonzero AQL does not give the supplier the right to either knowingly or unknowingly permit defective units of product to be sold to the consumer. This means that not only should the producer not deliberately put faulty products into the lot, but also that the inspector should identify all units which are observed to be obviously defective, regardless of whether or not those units are included in the inspection sample. Further, in selecting an inspection sample, the inspector must not deliberately include or exclude a unit because it is defective. After the sample has been drawn from the lot and inspected, those units previously observed and identified as being obviously defective but not included in the sample must be removed from the lot for disposition in accordance with established procedures for defective products.

14.3 Resubmitted Lots.

14.3.1 Screening and Resubmission. Screening done in connection with lot sampling plans is the procedure by which each unit of product in a rejected lot is inspected and each defective unit is rejected. A resubmitted lot is a lot that has been rejected, subjected to screening, and subsequently submitted again for acceptance. When the consumer rejects a lot, the producer may elect to screen and reprocess the units and resubmit the lot for inspection if not prohibited by contractual provisions. If the producer does elect to screen the rejected lot, the inspection must cover at least the characteristics in the inspection class(es) which caused lot rejection. However, units of product found during screening with defects belonging to other inspection classes should also be treated as defective (see 14.3.2).

14.3.2 Disposal of Defectives. Defective units found as a result of sampling or screening of rejected lots should not be mixed with production lots. At the discretion of the responsible authority defective units may be:

a. Reworked and accumulated over a period of time for subsequent resubmission as a miscellaneous lot which will be inspected for all characteristics.

b. Reworked and submitted with the lot from which they were screened.

c. Submitted by the supplier in a request for deviation approval.

d. Disposed of as scrap by the supplier.

e. Disposed of as agreed upon by the supplier and responsible authority.

14.3.3 Severity of Inspection. When resubmission is permitted, a decision must be made as to the severity of inspection necessary to assure the adequacy of screening and rework. A resubmitted lot should be given normal or tightened inspection, never reduced inspection. Also, sampling plans with an acceptance number of zero may be used.

14.3.4 Inspection of Resubmitted Lots. A decision must be made as to whether inspection of resubmitted lots is to be performed for all types or classes of defects or only for the particular types or classes of defects which caused initial rejection. This decision will depend to some extent on whether defects are correlated and on the nature of the work performed on the lot prior to its resubmission. If screening is all that was required, reinspection can be limited to the class of the defects that caused rejection. On the other hand, if the lot was reprocessed, a possibility exists that additional defects may have been introduced. In such instances, reinspection should be performed for all classes of defects. When reinspection is limited to the class of defects that caused rejection, defects of other classes may be observed during reinspection. Units containing defects in the other classes should be returned to the supplier for replacement if justified on the basis of cost. However, the observance of such defective units is not counted in the results of reinspection.

SECTION 15: ESTIMATED PROCESS AVERAGE

15.1 Purpose. The process average is the average percent defective or average number of defects per hundred units of product submitted by the supplier for original inspection. Original inspection is the first inspection of a particular quantity of product as distinguished from the inspection of product which has been resubmitted after prior rejection. The process average for a lot is estimated from sampling inspection data. The primary purpose of computing an estimated process average is to estimate the average quality of products which may be submitted and, based on this estimate, determine whether product quality is deteriorating, improving, or remaining constant. Estimated process averages fill a definite need in the construction of "p charts," control charts for fraction defective. These charts graphically show quality trends and can give guidance on the need for corrective action. They are also quite useful in comparing the quality of different suppliers of the same product, since their comparative product quality can be seen at a glance. The estimated process average may also be used by the consumer in specifying or changing AQLs in specifications or contracts. When the estimated process average is to be computed inspection should not be curtailed when the rejection number is reached before the entire sample has been inspected. Estimates taken from curtailed sampling results are biased (See 15.2.1) and thus may not be the best reflection of the true process average.

15.2 Computation. The following formula is used to compute the estimated process average in terms of percent defective:

$$\text{Estimated Process Average} = \frac{100 \times \text{Total number of defectives in the samples of k lots}}{\text{Total number of units in the samples drawn from k lots}}$$

where "k" is the number of lots from which samples have been drawn. A preferred procedure requires the estimated process average to be computed for 10 consecutive lots on original inspection (i.e., the inspection results of resubmitted lots are excluded). It is computed after every 5 lots following the tenth lot, but may be computed after each lot if the product quality is changing rapidly. The estimated process average is computed separately for each type or class of defects for which a separate AQL has been specified. To use the above formula for computing the estimated process average when the expression for nonconformance is in terms of defects per hundred units, the word "defectives" in the numerator is changed to "defects".

15.2.1 Computation for Double and Multiple Sample Plans. Computation of the estimated process average with double or multiple sampling plans may be made using data either from the first sample only or from all samples. Usually only data from the first sample is used, and the reason for preferring this method is that it always yields an unbiased estimate of the process average. When data from all samples is used, an estimate of the process average is computed which has the undesirable characteristic of being biased. That is, over the long run, estimates of the process average will not equal the true process average. Users of double or multiple sampling plans who wish to investigate the use of data from all samples may refer to Askin, Aloise and Guthrie, Donald, "A Biased Estimate of the Process Average", Technical Report No. 14, Applied Mathematics and Statistics Laboratory, 1954, Stanford University, Stanford, California.

15.2.2 Computations with Nontypical Conditions. The results of inspecting products manufactured under conditions not typical of usually production procedures (known as abnormal results) may be excluded from computing the estimated process average. The mere fact that the data look unreasonable is not a sufficient basis for excluding them. A definite reason must be known, such as a furnace failure, a disruption in electrical power service, or the equivalent.

Example 5: Estimated Process Average. Assume a product is to be submitted in lots of 2500 units. The sampling plan used calls for drawing a single sample of 125 units from each lot with an acceptance number of 3, rejection number of 4. The estimated process average is to be computed on the basis of the results of 5 consecutive lots on original inspection. It is known that lot number 3 received water damage from a leaking roof during a heavy rain storm and therefore the inspection results reflect an abnormal condition. The results of sampling inspection are tabulated as follows:

TABLE B: Estimated Process Average
(n= 125, Ac= 3, Re= 4)

Lot Number	Lot Size	Sample Size	Defectives Observed	Inspector Decision
1	2500	125	2	Accept
2	2500	125	1	Accept
(3)	(2500)	(125)	(9)	Reject (Abnormal)
4	2500	125	0	Accept
5	2500	125	4	Reject
(3)	(2500)	(125)	(0)	(Accept)
6	2500	125	1	Accept
TOTAL		625	8	

$$\text{Estimated Process Average} = \frac{100 \times 8}{625} = 1.28\% \text{ defective}$$

Note that lot number 5 was rejected on original inspection. When it has been screened and resubmitted, the inspection results for the resubmitted lot must not be included in the computations for the estimated process average although the original inspection results for lot number 5 are included. Lot number 3 is excluded from the computation due to the abnormal condition encountered.

SECTION 16: QUALITY HISTORY

16.1 Purpose. Quality history is the compilation of inspection, quality control, or reliability records for a unit of product, or a group of units. The quality history of suppliers producing the same product can be developed, and their quality capabilities can be evaluated. Process capability and design variability studies can be made to provide a factual basis for changes necessary to meet either quality or performance requirements. Deficiencies in unit of product or systems design can be brought to the attention of development, product, or systems engineering activities for corrective action. The importance of the quality history of a supplier for a specific product cannot be overstated. When the quality history is very good (the product is consistently high in quality for all characteristics), less inspection will be required and inspection costs will be reduced for both the supplier and the consumer.

16.2 Inspection Records. Inspection records consist of recorded data concerning the results of the inspection with appropriate identifying information as to the characteristic or class of characteristics inspected. The recording of sampling inspection data permits maintenance and continuity of quality history. By analyzing these data, adverse quality trends can be detected and corrective actions initiated. This makes possible the avoidance of frequent rejection of product costly delays in meeting production schedules and increases the supplier's responsibility for quality products. Better control over quality can be exercised when the facts are known and recorded. In order to develop a quality history, it is necessary to compile and maintain data regarding the results of inspection. These data permit the evaluations of the process capability. One of the best techniques for this evaluation is the estimated process average. It is essential that adequate records be maintained regarding the results of inspection regardless of the type performed. Standard forms should be used for this purpose. The records should provide complete identification of the product or operation inspected and, as applicable, information such as: the supplier, contract number, specification, instructions or project order, type of sampling used, lot size, sample size, quality level(s), and complete inspection results including acceptance or rejection decisions. Inspection records serve a number of useful purposes such as:

a. The compiled information can be used to determine the severity of inspection needed for current contracts or subsequent contracts with the same producer.

b. Inspection records indicate the producer's quality capability and integrity. They can be used in subsequent contract award decisions.

c. They are a source of feedback information to support request for waivers, engineering redesign, and investigation of complaints of defective products by the using activities.

16.3 Feedback Information. Feedback information is the collection or receipt of quality data reports regarding the product. Feedback information is most commonly generated by the user when a product fails to satisfy his needs under live environmental conditions; however, feedback also includes satisfactory reports, success data, in-service use data, etc. The inspector also generates feedback information on a product before it reaches the consumer. Feedback information can be used to aid in making valid decisions regarding adjustments of the product or process to prescribed requirements by alerting supervision to unsatisfactory performance as it occurs. The feedback of sampling inspection results, as well as the frequency and the nature of complaints from the consumer, is an important part of the total feedback picture which cannot be overstressed. This feedback is a major factor in the readjustment of quality levels, may provide a realistic and factual measure of the state of the art, and is also valuable in providing a basis for awarding incentive type contracts.

SECTION 17: RESPONSIBILITIES

17.1 Consumer Responsibilities. Basic responsibilities of the consumer will vary from one situation to the next. Those responsibilities may include the establishment of realistic quality requirements and an adequate amount of inspection to assure that product quality conforms to requirements. The consumer may operate a data feedback system to improve product design and quality requirements. Inspection by the consumer may be performed to determine the adequacy of the supplier's inspection system or quality program, except for inspections reserved for sole performance by the consumer. Normally, this is accomplished by the inspection of products that have already been inspected by the supplier and submitted for acceptance. Generally, the sample inspected by the consumer is selected separately from and independently of the sample selected by the supplier. Consumer inspection is usually in the nature of a verification inspection rather than a duplication of the supplier's inspection effort. Conformance inspection by the consumer consists of examinations and tests performed to ascertain whether the product meets standards established by the procurement documents. Each of these examinations and tests is characterized by a measurement or comparison which furnishes information relative to a standard established by the procurement documents. H-109, Statistical Procedures for Determining Validity of Suppliers' Attribute Inspection, provides more complete information about verification inspection.

17.2 Responsible Authority. Various military sampling standards refer to a "responsible authority." In general, the responsible authority referred to in the military standards is a representative, not of the supplier, but of the government agency which is procuring some product. In a general supplier/consumer situation, the responsible authority is some representative of the consumer.

17.3 Supplier Responsiblities. The supplier is responsible for controlling the production process which may generate products, produce data records, or result in the performance of defined operations, and for taking necessary actions to regulate or prevent the occurrence of defects. The supplier is required to perform all inspection, unless otherwise prescribed by the contract. The minimum amount of supplier inspection is usually specified by the Quality Assurance Provisions of specifications, purchase descriptions, or other contractual documents. Based on the results of his inspection, the supplier determines whether the products intended for submission to the consumer meet or do not meet the desired quality requirements. The decision as to whether the products should or should not be submitted rests with the supplier. The scope of the supplier's total quality effort is dependent on such factors as the importance of the product, the complexity of the product, the intended usage of the product, and the unit life cycle cost.

17.4 Consumer vs. Supplier. Inadequacies in the supplier's inspection can be demonstrated by objective evidence developed through product inspection. However, sampling variations can occur. It is important to know, when sampling inspection is used, whether any difference between supplier and consumer inspection results is real or can be considered to be due to chance alone. Procedures have been developed which permit a comparison between supplier and consumer inspection data for the purpose of determining evidence of significant statistical differences. Such a procedure has been published in US DOD Quality Control and Reliability Handbook (interim) H-109, Statistical Procedures for Determining Validity of Suppliers' Attributes Inspection. These methods may also be used in procurement, storage, and maintenance inspection operations, or whenever an independent check is desired of the reported fractions defective. Whenever a real difference exists between consumer and supplier inspection results, an investigation may be needed to determine whether or not his difference is due to misinterpretation of the inspection requirements. Problems arising from such situations can be minimized if certain administrative actions (on the part of the consumer) are taken. As a minimum, these actions should assure that both supplier and consumer inspection personnel are aware of the need for and understand the following:

a. Proper lot formation and control;
b. Drawing sample units of product in a random manner;
c. Clear description of a defect or defective unit;
d. Correct application of the sampling plan used;
e. Adequate maintenance and calibration of inspection equipment;
f. Uniformly applying quality standards in classifying sample units;
g. Preparation and maintenance of appropriate inspection procedures;
h. Agreement on the method of measuring conformance.

PART B: MIL-STD-105

SECTION 18: INTRODUCTION

18.1 General. This part of the handbook provides detailed instructions and illustrative examples for applying and administering the attribute sampling procedures established by MIL-STD-105. Nothing that follows in this part of the handbook shall be interpreted to be in contradiction with any statements in MIL-STD-105 since it is intended to serve only as an aid in support of that standard.

18.2 Editorial Comments. Numbers in square brackets in this part of the guide are references to the relevant paragraph numbers in MIL-STD-105. The tables in MIL-STD-105 are designated by roman numerals with sub-divisions denoted by capital letters (e.g.,

Table I, Table II-A, Table II-B, etc). The tables in this part of the guide are designated by arabic numerals (e.g., Table 1, Table 2, Table 3, etc). Tables will be referred to without specifying each time which document is the appropriate one, since this will be clear from the table numbers themselves. Reading this part of the guide is unlikely to be rewarding unless a copy of MIL-STD-105 is available for reference.

18.3 Scope and Purpose of MIL-STD-105. MIL-STD-105 is designed for attributes [1.4], lot-by-lot [5.1] inspection. The scheme is particularly relevant for inspection of a sequence of lots or batches, but an occasional isolated lot or batch may also be covered by considering the tables as a collection of sampling plans rather than as a sampling scheme. The main purpose of every MIL-STD-105 scheme is to accept with a high probability lots whose quality level is equal to or better than the Acceptable Quality Level (AQL) [4.2].

18.4 AQL in MIL-STD-105. MIL-STD-105 defines the AQL as the maximum percent defective (or the maximum defects per hundred units) that, for purposes of sampling inspection, can be considered satisfactory as a process average. Although the AQL is a number greater than zero, the fact does not give a manufacturer the right to knowingly or unknowingly supply any defective product, nor should that fact be taken to mean that the consumer is willing to accept defective product. Rather, the AQL should be regarded as an index to a sampling plan and, thereby, to the calculated risks that the supplier and the consumer are prepared to accept in order to obtain the economic benefit of sampling inspection. The sampling plan indexed by the AQL is most effective (1) if, when the manufacturer is producing at a quality that is worse than the AQL, the plan rejects sufficient lots to make it worthwhile to improve product quality without delay, and (2) if, when the manufacturer is producing at a quality that is at or better than the AQL, the plan rejects very few lots. It is often difficult and expensive to be sure (through 100% inspection) that a machine, a process, or a production line is producing no defectives. In practice, some percentage of defectives can usually be tolerated, and that percentage is largely governed by economic considerations as the customer may be faced with the choice between a reasonably good article that he can afford or a better one that is beyond his means. If no percentage of defective product can be tolerated, then the product must be inspected 100% or more.

18.5 Structure of MIL-STD-105. MIL-STD-105 may be considered as consisting of three parts, namely the text, the master tables (Tables I to IX), and the extended tables (Tables X-A to X-S). The text defines the terms used and gives rules for the operation of sampling inspection. The right-hand pages of the extended tables repeat information already given in the master tables. It proves useful in practice to have this information available in two different forms of layout; sometimes one layout is the more useful, sometimes the other. The scheme is based upon the use of the AQL concept, and the plans are indexed by AQL and by sample size. The sample size is determined from the sample size code letter (see para 23.2) and from the inspection level [9.2]. Equivalent single sampling, double sampling and multiple sampling plans are given [9.5]. Tables are given for normal inspection, tightened inspection, and reduced inspection [8] together with rules for switching from one of these to another [8.3].

SECTION 19: APPLICABILITY OF MIL-STD-105

The sampling plans in MIL-STD-105 are applicable, but not limited, to attribute inspection of the following:

a. End Items. These are completed products that may be inspected before or after packaging and packing for shipment or storage.

b. Components and Raw Materials. These are the materials which are shaped, treated, or assembled to form the end items. These materials may be inspected at their source, upon receipt at the point of assembly, or at any convenient place along the assembly process where the end items are formed.

c. Operations. In many cases, repetitive work performed by machines and operators can be judged to be acceptable or unacceptable. These work operations may be inspected on a sampling basis to determine whether the process machine, operator, or clerk is performing satisfactorily.

d. Materials in Process. Materials may be inspected on a sampling basis to determine their quality after any step along the production line. Inspection may be for quality characteristics which were built into the materials by the production process or for damage or deterioration which occurred while the materials were in temporary storage between production steps.

e. Supplies in Storage. The sampling procedures and tables of MIL-STD-105 can be used to determine the quality of supplies in storage on a sampling basis.

f. Maintenance Operations. These operations are usually performed on reparable materials to restore them to a serviceable conditions. When maintenance or overhaul operations are performed, attribute inspection is made to determine the quality of the product after reconditioning operations have been completed.

g. Data or Records. Whenever large volumes of data are processed (i.e., accounting records, cost data, invoices, bills of lading, etc.), the attribute sampling inspection procedures of MIL-STD-105 can be used as the basis for determining dollar volume, item count, accuracy, or other measure of quality of the data or records.

h. Administrative Procedures. If the results of administrative procedures can be measured on an attribute basis, the sampling plans and procedures of MIL-STD-105 can be applied.

SECTION 20: SEQUENCE OF OPERATIONS IN USING MIL-STD-105

A typical sequence of operations in using the sampling procedures and tables for inspection by attributes of MIL-STD-105 is illustrated by Table C which follows. This table assumes a requirement for single sampling.

TABLE C: Sequence of Operational Steps

Steps	Explanation
1. Determine lot size.	1. Lot size controlled by lot formation criteria contained in procurement documents. Otherwise, establish by agreement between responsible authority and supplier.
2. Determine inspection level.	2. If the item specification does not give the inspection level, use inspection level II.
3. Determine sample size code letter.	3. Found in Table I, MIL-STD-105, based on lot size and inspection level.
4. Determine sampling plans.	4. Single sampling generally selected. Double or multiple sampling may be used.
5. Establish severity of inspection.	5. Normal inspection generally used at start of contract or production.
6. Determine sample size and acceptance number.	6. Assuming normal inspection and giver the specified AQL value and the sample size code letter, the sample size and acceptance number are found in Table II-A, MIL-STD-105.
7. Select sample.	7. The sample, consisting of the numbe of units of product as determined from Table II-A, MIL-STD-105, is selected at random from the lot. Additionally, any obvious defectives that have not been selected for the inspection sample are removed from the lot (but are not included in the sample). (See para. 14.2
8. Inspect sample.	8. The defectives (or defects) are counted. If this count does not exceed the acceptance number (Ac), the entire lot is accepted. If the count equals or exceeds the rejection number, the lot is rejected.
9. Record inspection results.	9. Compute estimated process average if required by operating procedures. Maintain record of accept/reject decisions in order that switching rules may be followed.

Steps	Explanation
10. Resubmit lot.	10. If the lot is not accepted, it may be resubmitted for acceptance inspection only after all units of the lot are reinspected and all defective units removed or reworked.

Example 6: Obtaining a Plan. Suppose the AQL is 1.0, the inspection level is II and the lot size is 2,500. The first thing required is the sample size code letter (usually called simply the code letter, for short). For a lot size of 2,500 and inspection level II, Table I gives the code letter as K. In the appropriate master table (Table II-A), it is found that the sample size for single sampling is 125. AQLs for normal inspection are given along the top of the table, and under the value 1.0 we find the numbers 3 and 4 given under the heading Ac Re (which stand for acceptance number and rejection number, respectively). The sampling plan required is:

Sample size	125
Acceptance number	3
Rejection number	4

Alternatively, Table X-K-2 could be used. Again the sample size of 125 is found; and in the column for AQL 1.0 are found the acceptance and rejection numbers 3 and 4 as before.

Example 7: Arrows in Tables II, III, and IV. Suppose the AQL is 0.40, the inspection level is I, and the lot size is 230. Table I gives the code letter as E. Using Table II-A, it is found that there is no plan for letter E and AQL 0.40 but a downward pointing arrow that directs us to letter G instead, and the required plan is:

Sample size	32
Acceptance number	0
Rejection number	1

Alternatively, the specifying of code letter E leads us, in the extended tables, to Table X-E-2. But this page has no column for AQL 0.40. Instead, the symbol of and inverted triangle appears for AQLs less than 1.0. This triangle refers to the footnote "Use next subsequent sample size code letter for which acceptance and rejection numbers are available." If the triangle is thought of as an arrowhead, it is pointing towards the edge of the page to be turned. This leads to letter F where again AQL 0.40 is not given, and on to letter G to find the same plan as before. It is very important to remember that if a triangle or series of triangles directs you from one page to another of the extended tables, or an arrow directs you from one row to another of the master tables, the sample size to be used is the one given for the new page or the new row arrived at and not the one given for the original page or row [9.4]. Where upward pointing arrows or triangles are found the meaning is similar. The triangles again point to the edge of the page to be turned.

Example 8: Sample Size Exceeds Lot Size. Suppose the AQL is 0.015, the inspection level is III and the lot size is 120. Table I gives the code letter as G, but, referring to the tables, an arrow (or a series of triangles) leads to letter P before a plan is found. The required plan has a sample size of 800 which exceeds the lot size. In this case the entire lot of 120 has to be taken as the sample. The acceptance and rejection numbers remain as 0 and 1.

MIL-STD-105 states that AQL values of 10 or less shall be expressed either in % defective or in defects per hundred units whereas values over 10 shall be expressed only in defects per hundred units [4.5]. A decision must be made as to whether defects or defectives is appropriate in each particular case. The AQL will then be defined in terms of that decision. Examples 6, 7, and 8 are incomplete, then, because in each of them the AQL and the acceptance and rejection numbers are given as pure numbers. However, as examples for demonstrating how to draw sampling plans from the tables, they are satisfactory.

Example 9: Defects Per Hundred Units And Defectives. This example takes Example 6 one step closer to being a real world problem by expressing the AQL and the acceptance and rejection numbers in terms of defects and then defects per hundred units. In example 6 the AQL is 1.0 and the sampling plan is:

Sample size	125
Acceptance number	3
Rejection number	4

If the AQL is 1.0% defective, the sampling plan will be:

Sample size	125
Acceptance number	3 defectives
Rejection number	4 defectives

If the AQL is 1.0 defect per hundred units, the sampling plan will be:

Sample size	125
Acceptance number	3 defects
Rejection number	4 defects

The tables, it will be seen, are used in precisely the same manner in either case.

SECTION 21: PREFERRED AQLs

The tables in MIL-STD-105 give 26 values of AQLs ranging from 0.010 (i.e., one defective per 10,000 units of product) to 1,000 (i.e. 1,000 defects per 100 units of product or an average of 10 defects per unit). These 26 values are chosen so that each is approximately one and a half times as large as the previous one (the average ratio is in fact the fifth root of 10, or 1.585). When the specified AQL for inspecting any given product is one of these preferred AQLs the tables may be used. If, however, a specified AQL is not a preferred AQL the tables are not applicable [4.6]. In these circumstances, the appropriate quality assurance personnel must either determine that a preferred AQL may be used in place of the specified AQL or that a new sampling plan must be developed that satisfies the requirements of the specified AQL. The very high values of AQL, 100 and above, are not likely to be used often, since they imply that a product in which every unit contains defects may be considered satisfactory. Clearly, this could be so only if the defects being sought were of a minor nature, and the unit of product was something fairly complex, such as a complete vehicle.

Example 10: High AQLs. In the inspection of cloth, to be made up later into clothing, the unit of product might be a considerable area of cloth. In the inspection for minor weaving faults, an average of 4 faults per square meter might well be acceptable, in which case an AQL of 400 defects per hundred square meters could be specified.

SECTION 22: INSPECTION LEVELS

22.1 General. Inspection levels in general provide the quality engineer a means by which one of several sample size code letters may be selected for a given lot size. The effect of offering this choice is to offer several sampling plans, each with approximately the same probabilities of acceptance in the region of good quality (AQL or better) but with differing probabilities of acceptance when lot quality is worse than the AQL. Table I gives three general inspection levels, numbered I, II, and III and four special inspection levels, numbered S-1, S-2, S-3, and S-4. The general levels will be the most often used, and it is assumed that level II will be used unless one of the other levels is specified [9.2].

Example 11: Comparison of Inspection Levels. For a lot size of 600, the inspection levels are:

Inspection level	Code letter	Sample size (Single sampling)
I	G	32
II	J	80
III	K	125

It must be remembered, however, that for certain AQLs the arrows in the table will lead to sample sizes different from these.

22.2 Special Inspection Levels. The special inspection levels are designed for situations where the sample size must be kept small. A typical situation in which a special inspection level might be used is one in which testing is expensive or destructive and in which large consumer risks can be tolerated. Section 37 contains a discussion of problems that the responsible authority must face in setting the inspection level [9.2].

SECTION 23: SAMPLE SIZE

23.1 Sample Size Relative to Lot Size. The amount of information about the process quality gained from examining samples depends mostly upon the absolute size of the samples and little upon the percentage of the lot that is examined. It is sometimes asked, therefore, "Why is the sample size made to depend upon the lot size?" There are three reasons:

a) a sample of small size that has a high probability of representing the quality of a small lot or batch may be too small to represent, with high probability, the quality of a larger lot or batch;

b) when there is more at stake, it is more important to make the right decision. Proper use of the tables leads to the result that from a good process lots are more likely to be accepted as the lot size increases, whereas lots from a bad process conversely are more likely to be rejected;

c) with a large lot a sample size can be afforded that would be uneconomical for a small lot. For example, a sample size of 80 from a lot of 1,000 may be easy to justify economically, where a sample of 80 from a lot of 100 would be relatively expensive.

23.2 Sample size in MIL-STD-105. The sample sizes given in MIL-STD-105 for single sampling form a series (like the series of AQL values) in which each number is about 1.585 times the preceding one. This means that the product, AQL times sample size, is approximately constant on diagonals of Table II-A which leads to a self-consistent table if acceptance numbers are also taken as constant on diagonals. This feature was helpful in designing the tables rather than being directly helpful in using them, but the resulting pattern does mean that the tables lend themselves to the construction of convenient summaries and of special nomograms or slide-rules that could be convenient on occasions. The sample sizes for double and multiple sampling follow the same pattern, but for a given code letter the size of each of the two double samples is equal to the single sample size of the previous code letter, whereas, each of the seven multiple sample sizes is equal to the single sample size of the third previous code letter. Sample sizes for reduced inspection are always equal to the normal inspection sample size for the second previous code letter. As a result, six different values of sample size correspond to any given code letter according to whether single, double or multiple sampling is used, and to whether or not reduced inspection (See Section 28) is in force. This is why code letters, rather than purely sample sizes, are needed to index tables.

SECTION 24: NORMAL INSPECTION

24.1 Consumer Protection. A problem in designing a sampling plan or a set of sampling plans is to decide how the OC curve(s) of the plan(s) will relate AQL quality to probability of acceptance of a lot or batch of product. Suppose, for example, that the sampling plan is designed such that when product quality is at the AQL, the probability of lot acceptance is very low, as illustrated in Figure 6. With such a sampling plan, the probability of lot acceptance is also small when lot quality is worse than the AQL, and the customer is very well protected from receiving low quality product. The manufacturer, however, will be unhappy when he produces at the AQL (see para 18.4) only to have his product rejected. Furthermore, because of the nature of sampling plans, producing at a quality level better than the AQL will not necessarily mean a high probability of lot acceptance. In the example of Figure 6, when the product quality level is at half the AQL, only 20% of the lots will be accepted, and when product quality is at one quarter of the AQL, only about half of the lots will be accepted. Not only the manufacturer, but also the customer will be unhappy with such a situation, especially if frequent lot rejections are delaying delivery of the product.

24.2 Producer Protection. Another approach might be to use a sampling plan in which there is a high probability of lot acceptance at the AQL. Figure 7 shows the OC curve of such a sampling plan. Not only is product with quality at the AQL accepted with high probability, but also all product with quality higher than the AQL and when quality is in that region, both the customer and the manufacturer are happy. However, if product quality drops below the AQL, there may still be a high probability of lot acceptance. In Figure 7, if product quality drops to twice the AQL, there is still a 60% chance of lot acceptance. While this result will probably please the manufacture, it will, on the other hand, probably displease the customer.

24.3 Compromise. To meet the requirements of both the manufacturer and the customer, some compromise is needed, and the device adopted in MIL-STD-105 is that of normal inspection and tightened inspection, in which two sampling plans are specified for any given situation, together with rules for determining when to switch from one to the other and back again [8]. Normal inspection is designed, like the example in Figure 7, to protect the manufacturer against having a high proportion of lots rejected even though his quality is better than the AQL. In effect, the manufacturer is being given the benefit of any doubt that arises due to sampling variability. But the customer needs protection too, and this is achieved by arranging that the manufacturer shall not be given the benefit of the doubt blindly and invariably, but only for as long as he proves worthy of it. If at any time the sampling results show that an excessive number of lots have been rejected, he forfeits his right to the benefit of the doubt (that is, his right to normal inspection), and tightened inspection is instituted to protect the customer.

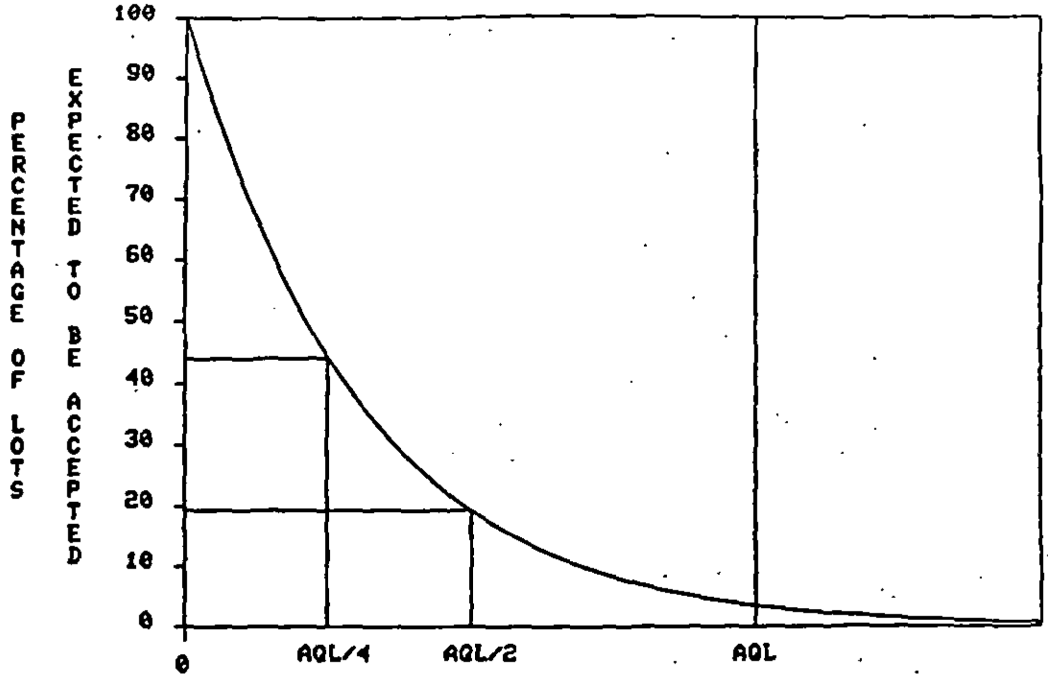

FIGURE 6. OC CURVE OF A SAMPLING PLAN WITH A HIGH PROBABILITY OF REJECTING LOTS HAVING QUALITY WORSE THAN THE AQL

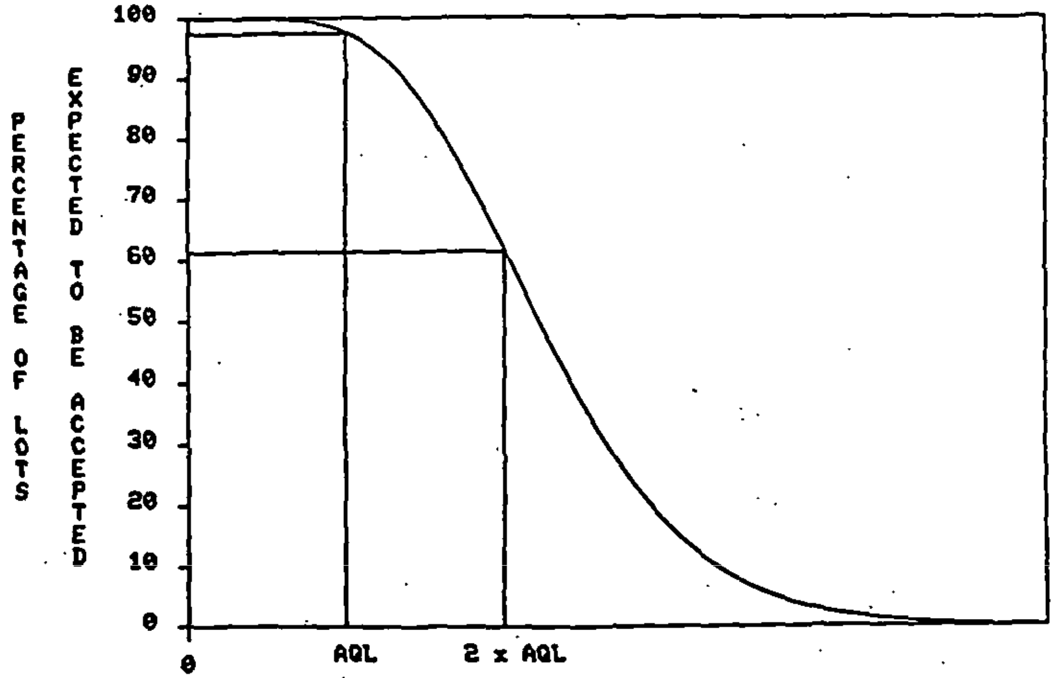

FIGURE 7. OC CURVE OF A SAMPLING PLAN WITH A HIGH PROBABILITY OF ACCEPTING LOTS HAVING QUALITY BETTER THAN THE AQL

SECTION 25: TIGHTENED INSPECTION

25.1 Finding the Plan. When tightened inspection is called for, the required plan is drawn from the tables in just the same way as plans for normal inspection except that Table II-B is used instead of Table II-A if the master tables are used, whereas if the extended tables (Table X) are used, the appropriate column of the table is found by reading the AQL value from the bottom of the table instead of from the top.

25.2 The Tightened Sampling Plan. In general it will be found that a tightened plan has the same sample size as the corresponding normal plan but a smaller acceptance number. However, if the normal inspection acceptance number is 1, changing to 0 would lead to an unreasonable degree of tightening, and if the normal inspection acceptance number is 0, no smaller number is available. In both of these cases, tightening is performed by keeping the acceptance number the same as for normal inspection while increasing the sample size.

25.3 O.C. Curves. O.C. curves for tightened inspection are not shown graphically so as to avoid confusing the diagrams by trying to get too much into them. However, tabulated values are given, and where a plan exists both as a normal plan for one AQL and as a tightened plan for a different AQL, which is often the case, the same O.C. curve applies to the plan in both its guises. It must be remembered that the figures used to label the curves refer to the normal inspection AQL values.

Example 12: Finding a Tightened Plan. Suppose the AQL is 1.0, the inspection level is II, the lot size is 2,500. From Table I, the code letter is K. Using Table X-K-2, the tightened plan is:

Sample size	125
Acceptance number	2
Rejection number	3

This is the same as the normal plan for code letter K and AQL 0.65. Its O.C. curve is therefore the one labelled 0.65 in chart K.

SECTION 26: SWITCHING RULES

26.1 General. The last two sections have discussed normal inspection and tightened inspection, what each is designed to do, and how to use the tables in the standard to find the appropriate sampling plans. This section discusses the switching rules by means of which the decision is made to change from normal to tightened or back again [8.3]. The plans in the standard have been designed primarily for use with a continuing series of lots or batches. When the standard is in fact used in such a situation (the isolated lot situation being an exception), it must be emphasized that the rules for switching between normal and tightened inspection are an essential part of the sampling scheme.

26.2 Normal to Tightened. Since normal inspection is designed to accept nearly all the lots offered provided that the quality is at least as good as the AQL, it follows that if a high proportion of lots is being rejected, the quality probably is not as good as the AQL. The question is what proportion of rejection over what number of lots is high enough to require a switch from normal to tightened inspection? A rule is required that will give reasonably quick reaction if quality becomes intolerable, while having a low probability of wrongly calling for tightened inspection when the quality is really tolerable. The rule for switching from normal to tightened inspection is that tightened inspection must begin as soon as two out of five successive lots have been rejected on original inspection (See 3.3.1.) Thus, if lots are rejected but resubmitted after being reworked, these resubmitted lots are not counted for switching rule purposes. The rule can be interpreted to read two out of five or fewer, to allow for the situation where two are rejected near the beginning of production before five lots have been produced. In these circumstances tightening should be introduced at once without waiting for five.

26.3 Tightened to Normal. Once tightened inspection has been instituted, normal inspection is not restored until five successive lots have been accepted on tightened inspection. This requirement is quite a severe one, and it was intentionally made that way because once there is evidence that intolerable quality has been produced, the manufacturer's right to the benefit of the doubt is lost and cannot be restored until he has shown that it is safe to do so.

26.4 Discontinuance of Inspection. There is one further safeguard for the customer. This is the rule that acceptance inspection may be discontinued, pending action to improve the quality, if ten (or other number if specified by the responsible authority) consecutive lots remain on tightened inspection [8.4]. This is a most important principle; if the quality is bad, action is needed, and inspection should stop until evidence is provided that suitable corrective action has been taken. Once corrective action has been taken, tightened inspection may resume [8.2].

Example 13: Normal to Tightened. A product is being supplied in lots of 4,000. The AQL is 1.5% defective. The inspection level is III. Single sampling is being employed. Table I gives the code letter as M, and the required sampling plans are found to be:

	Normal Inspection	Tightened Inspection
Sample size	315	315
Acceptance number	10	8
Rejection number	11	9

Table D shows the results of the inspection of the first 25 lots. It is usual to use normal inspection at the start of a production run and this is done here. The rejections at lots 4 and 10 do not cause a switch to tightened inspection since in each case the 2 in 5 rule has not been met, but the rejection at lot 12 following the one at lot 10, causes a switch for lot 13 onwards. At lot 21, five successive lots have been accepted on tightened inspection, and normal inspection is restored beginning with lot 22.

TABLE D - Twenty-five lots from a hypothetical inspection process AQL = 1.5% defective. Inspection level III (See example 13)

Lot Number	Lot Size	Sample Size	Ac	Re	Defectives	Disp.	Future Action
1	4,000	315	10	11	7	Ac	cont. normal
2	4,000	315	10	11	2	Ac	cont. normal
3	4,000	315	10	11	4	Ac	cont. normal
4	4,000	315	10	11	11	Re	cont. normal
5	4,000	315	10	11	9	Ac	cont. normal
6	4,000	315	10	11	4	Ac	cont. normal
7	4,000	315	10	11	7	Ac	cont. normal
8	4,000	315	10	11	3	Ac	cont. normal
9	4,000	315	10	11	2	Ac	cont. normal
10	4,000	315	10	11	12	Re	cont. normal
11	4,000	315	10	11	8	Ac	cont. normal
12	4,000	315	10	11	11	Re	switch to tightened
13	4,000	315	8	9	7	Ac	cont. tightened
14	4,000	315	8	9	8	Ac	cont. tightened
15	4,000	315	8	9	4	Ac	cont. tightened
16	4,000	315	8	9	9	Re	cont. tightened
17	4,000	315	8	9	3	Ac	cont. tightened
18	4,000	315	8	9	5	Ac	cont. tightened
19	4,000	315	8	9	2	Ac	cont. tightened
20	4,000	315	8	9	7	Ac	cont. tightened
21	4,000	315	8	9	6	Ac	restore normal
22	4,000	315	10	11	7	Ac	cont. normal
23	4,000	315	10	11	2	Ac	cont. normal
24	4,000	315	10	11	5	Ac	cont. normal
25	4,000	315	10	11	3	Ac	cont. normal

26.5 Normal - Tightened OC Curves. The OC curves in Table X of MIL-STD-105 are for the normal sampling plans and for some of the tightened sampling plans in the standard. However, the standard provides no OC curves for the normal-tightened sampling schemes that are required for inspecting all continuing series of lots. This handbook provides those OC curves in Appendix C.

SECTION 27: METHODS FOR REDUCING RISKS

27.1 General. There must always be risks in sampling inspection, both of the acceptance of bad lots and of the rejection of good lots. But these risks should be tolerable provided that the AQL and inspection level have been well chosen. If either the manufacturer or the customer should decide in a particular instance that the risk he is taking is too high, it would be well to check that the AQL and the inspection level have been well chosen, but for the remainder of this section it will be assumed that they have been and that these are not available for change. The manufacturer will be interested in reducing risks when quality is better than the AQL - he is not entitled to any reduction of risk otherwise. The customer will be particularly interested in the risks when quality is worse than the AQL, since if quality is better than the AQL he is getting quality that offers few if any defectives in the lot.

27.2 <u>Four Methods</u>. There are four methods that can be used to reduce the risks for both parties.

a. The first method is to improve the quality of production. This may seem too obvious to be worth saying, but it is surprisingly easy in discussions on sampling plans, O.C. curves, switching rules, etc., to forget the simple rule that a low percentage defective in the production gives the customer what he wants and ensures a high proportion of acceptance to the manufacturer.

b. The second method applies only in a particular case, but it is the case which is most likely to cause anxiety, namely, where the acceptance number is 0. Plans with a zero acceptance number have such shallow O.C. curves that big risks are unavoidable. For this reason, MIL-STD-105 allows the use of an alternative when the tables lead to a zero acceptance number (provided the responsible authority approves). This alternative is to use the plan for the same AQL, with an acceptance number of 1, instead of 0 [9.4]. There is a price to be paid, in that a sample size about four times as big is required, but the risks for both parties are so much reduced that it is often well worth while. The price may be reduced somewhat by adopting the double or multiple sampling plan equivalent to the single sampling plan with acceptance number of 1.

c. The third method is to consider the possibility of increasing the lot size. If the lot size can be increased far enough to lead to a change of code letter and an increase of sample size, this will reduce the risks for both parties, since the larger sample size leads to a steeper O.C. curve, and the tables are so arranged that this curve will be higher than the old curve at most points where quality is better than the AQL, and lower at most points where quality is worse than the AQL. It is, unfortunately, not possible to arrange the tables so that these features are always as desired without losing other desirable features. Figure 8 shows, as an example, four of the normal inspection plans associated with an AQL of 1.5% defective. For quality better than the AQL, it is seen that the larger the sample the higher is the proportion of lots accepted. However, for quality worse than the AQL, plans with the larger sample sizes do not at all points give a greater probability of rejection than do plans with smaller sample sizes. Most of the curves cross relatively close to the AQL. The notable exception is the curves for sample sizes thirty-two and fifty which cross at roughly four times the AQL. The idea of increasing lot sizes to gain better protection with the resultant larger sample may be objected to since it is not always easy or sensible to change lot sizes. Lot sizes are fixed according to such things as continuity of production, the quantity of production that can be handled at one time, transport problems, stock control problems, and so on. It is nevertheless worth remembering that, other things being equal, an increased lot size can be helpful from the sampling inspection point of view. In examining the height of the curves in Figure 8 where percent defective is twice, three times, and four times the AQL, it must be remembered that the curves show only part of the picture - the normal inspection part. For all the normal inspection plans in MIL-STD-105, the percentage of lots accepted, if quality is twice the AQL, is less than 80%. Such an acceptance rate will always lead to tightened inspection before long.

d. In situations where the entire MIL-STD-105 sampling scheme (normal-tightened-reduced) is in use, it may become undesirable to take the extra consumer's risk that comes with reduced inspection. In this event, the responsible authority may decide to discontinue reduced inspection [8.3.3d] and use a sampling scheme which entails only the required normal and tightened inspection [8.3.1].

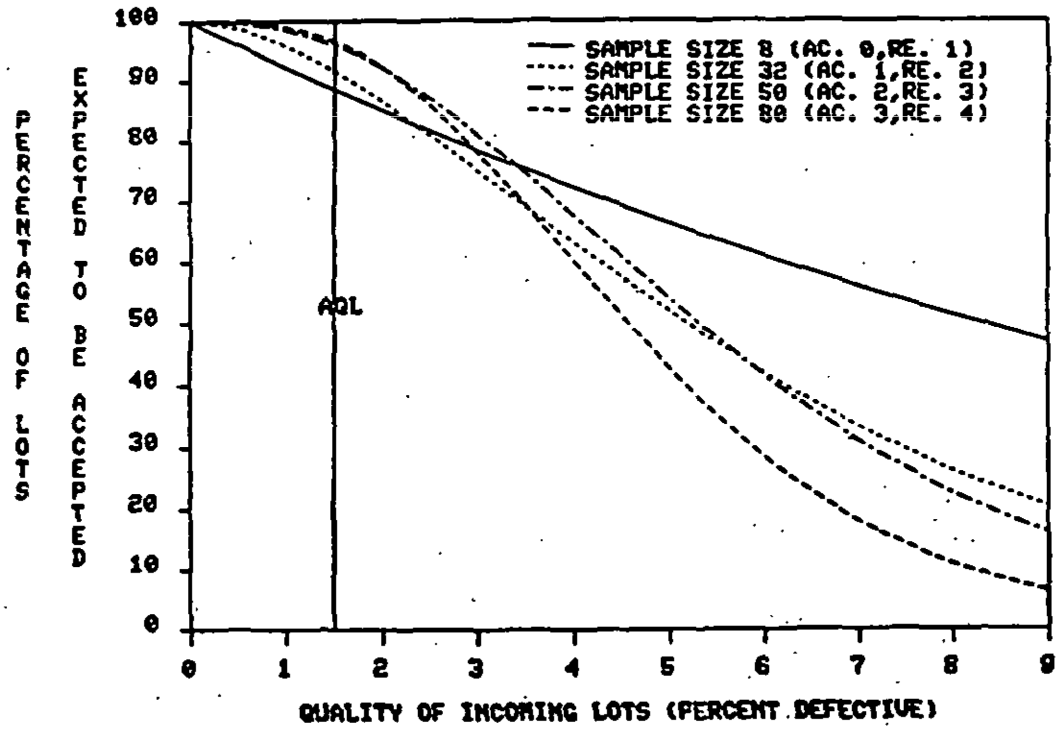

FIGURE 8. OC CURVES FOR SAMPLING PLANS WITH AQL 1.5% DEFECTIVE, NORMAL INSPECTION SINGLE SAMPLING

SECTION 28: REDUCED INSPECTION

28.1 General. Sometimes there is evidence that the production quality is consistently good. Where this happens and there is reason to suppose that the good production will continue, having the ability to detect bad lots will be less important, since nearly all the lots will be good ones. Inspection cannot, however, be stopped altogether since a warning is needed if the production quality worsens. In these circumstances, considerable savings can be made if so desired by using reduced inspection sampling plans, which have sample sizes only two-fifths the size of the corresponding normal inspection plans (except where the normal inspection plan has a sample size less than 5). It might at first be thought that the way to reduce the sample size would be to use a code letter earlier in the alphabet. This would indeed reduce the sample size, but would have the undesirable effect of also reducing the proportion of lots expected to be accepted when product quality is good; this would, in effect, mean punishing the manufacturer for doing good work. Since such a result would clearly be unsatisfactory, a special set of sampling plans is necessary for reduced inspection. These plans are given in Table II-C of the master tables.

Examination of Tables II-A and II-C will show that in addition to the three-fifths reduction in sample size, the reduced sampling plans are changed from the normal plans by increasing their acceptance number. Recalling the discussion of 10.3.2, it is seen that reducing the sample size and increasing the acceptance number reduce the slope of and shift to the right the location of the OC curve for normal sampling. The shift of the curve is sufficient to preserve the proportion of lots accepted at the AQL.

The use of tightened inspection, when called for by the switching rules, is essential to the scheme, but reduced inspection is entirely optional; even if the necessary switching rules are met, the responsible authority need not introduce it unless he wishes to. The switching rules [8.3.3] are designed to ensure that reduced inspection is not introduced unless the observed quality is genuinely good and is likely to continue so. To detect whether reduced inspection is permissible, the recent production history must be compared with a limit number, taken from Table VIII.

Example 14: A product is being manufactured to be inspected under the following conditions: AQL 10% defective, lot size 4,000, inspection level I, single sampling. The plan, sample size 80, acceptance number 14, rejection number 15, is found under code letter J.

Table E shows the imaginary results of the inspection process. Normal inspection is in use at the beginning of the table, which is taken to be an extract from a longer sequence, so the lot numbers do not start at 1. The results are good, all lots being accepted, with the number of defectives in each sample well below the acceptance number. After the inspection of the sample from lot 71, the inspector decides to ask whether reduced inspection would be permissible. He counts the total number of defectives observed in the samples from the last 10 lots and finds it to be 70. The number of sample units from the last 10 lots is 800, and looking against 800 and an AQL of 10 in Table VIII, the limit number is found to be 68; 70 is too many and reduced inspection is not permissible. After very good results from the next four lots, he decides to try again after lot 75. The observed number of defectives from the last 10 lots is now only 54, which is well within the limit number. Reduced inspection is now permissible provided that the previous 10 lots have all been accepted on normal inspection (which is the case), that production is at a steady rate, and that the responsible authority gives approval.

TABLE E - Fifteen lots from a hypothetical inspection process

AQL = 10% defective. Inspection level I (See example 14)

Lot Number	Lot Size	Sample Size	Ac	Re	Defectives	Disp.	Future Action
61	4,000	80	14	15	7	Ac	cont. normal
62	4,000	80	14	15	5	Ac	cont. normal
63	4,000	80	14	15	7	Ac	cont. normal
64	4,000	80	14	15	6	Ac	cont. normal
65	4,000	80	14	15	9	Ac	cont. normal
66	4,000	80	14	15	7	Ac	cont. normal
67	4,000	80	14	15	9	Ac	cont. normal
68	4,000	80	14	15	8	Ac	cont. normal
69	4,000	80	14	15	6	Ac	cont. normal
70	4,000	80	14	15	5	Ac	cont. normal
71	4,000	80	14	15	8	Ac	cont. normal
72	4,000	80	14	15	4	Ac	cont. normal
73	4,000	80	14	15	3	Ac	cont. normal
74	4,000	80	14	15	1	Ac	cont. normal
75	4,000	80	14	15	3	Ac	switch to reduced

28.2 Remaining on Reduced Inspection. Just what is meant by "a steady rate" calls for some interpretation, and this may well vary from one industry to another. Basically, the requirement is that there should have been no break in production sufficient to invalidate the argument that the present quality is almost certainly good, because the record of the recent past is so good. The precise meaning in any particular case must depend upon technical judgement based upon the consideration of all factors, the variation of which can affect the quality of the product.

28.3 Reduced to Normal. Since reduced inspection is optional, the restoration of normal inspection is allowed any time either supplier or consumer desire, and should be made if production becomes irregular or delayed, or if other conditions make it seem necessary. A return to normal inspection is required if a lot is not accepted on reduced inspection. The reduced sampling plans have the unusual feature of a gap between the acceptance and rejection numbers. The rules are that if the observed number of defectives is equal to the acceptance number or less, the lot is accepted and reduced inspection is continued (provided that other conditions do not call for normal inspection). If the rejection number is reached or exceeded, the lot is rejected and normal inspection begins with the next lot. If, however, the result falls in the gap between the acceptance and rejection numbers, the lot is accepted but normal inspection must be restored [10.1.4].

Example 15: Reduced to normal. Table F continues the example of Table E. The reduced plan is found from Table II-C to be:

Sample size	32
Acceptance number	7
Rejection number	10

As far as lot 81, 7 defectives or fewer are found in each sample and reduced inspection continues, but the 9 defectives of lot 82 call for a restoration of normal inspection even though the lot is accepted.

TABLE F - Ten lots from a hypothetical inspection process

AQL = 10% defective. Inspection level I (See example 15)

Lot Number	Lot Size	Sample Size	Ac	Re	Defectives	Disp.	Future Action
76	4,000	32	7	10	5	Ac	cont. reduced
77	4,000	32	7	10	2	Ac	cont. reduced
78	4,000	32	7	10	7	Ac	cont. reduced
79	4,000	32	7	10	3	Ac	cont. reduced
80	4,000	32	7	10	1	Ac	cont. reduced
81	4,000	32	7	10	4	Ac	cont. reduced
82	4,000	32	7	10	9	Ac	restore normal
83	4,000	80	14	15	17	Re	cont. normal
84	4,000	80	14	15	12	Ac	cont. normal
85	4,000	80	14	15	15	Re	switch to tightened

28.4 Sample Sizes. The sample sizes for reduced inspection will be seen to follow the same series of numbers as for normal inspection, but set two steps back on the scale of sample size code letters. This again gives constancy on diagonals.

28.5 O.C. Curves. Since reduced inspection is optional within the MIL-STD-105 framework, no reduced inspection OC curves are given either in the standard or in this handbook.

28.6 Limit Numbers for Reduced Inspection. Sometimes reference to Table VIII will disclose an asterisk instead of an entry. This means that the number of sample units from the last 10 lots is not sufficient to judge whether reduced inspection is allowable, in which case a greater number than 10 lots must be considered before reduced inspection may begin. The standard provides no rule for establishing what this number is to be, leaving its determination to the responsible authority [8.3.3d].

SECTION 29: CONCESSIONS

29.1 An Acceptable Concession. Concessions are a standard part of procurement practice. Some would say much too standard a part. But although the practice should not be overdone, it is clearly legitimate for a customer to decide that although certain articles are defective, he cannot wait, and, therefore, he will accept the articles, possibly at a reduced price. There is nothing in the system of procurement that prevents an appropriate representative of the customer from doing this if he wishes to. If such a concession is made, and a "rejected" lot is accepted for any special reason, it should still be recorded as a rejected lot for purposes of the switching rules.

29.2 An Unacceptable Concession. There is, however, another type of concession that there is a temptation to adopt when using sampling inspection. This is to accept, even though the sampling plan says "reject", not because the customer decides that he would sooner take defectives than have to wait, but because the sampling plan seems to have rejected the lot by only a small margin. The temptation may be particularly strong if rejection means not only rejection of the lot but also a switch to tightened inspection. This is a temptation that must always be strictly avoided; if the sampling plan says "accept for 3, reject for 4", it does not mean "accept for 4 reject for 5".

Example 16: Discussing a Concession. Inspection is being performed under the conditions AQL 10.0% defective, code letter E, normal inspection, single sampling. The sampling plan is:

Sample Size	13
Acceptance number	3 defectives
Rejection number	4 defectives

The inspection of a particular lot shows 4 defectives in the sample of 13. The inspector intends to reject the lot, but the manufacturer says to him "Look! There were only 4 defectives found. That is right on the border-line; just a matter of chance. It could easily have gone the other way. Look at all these good ones in the rest of the lot, which you have not inspected. Any one of them might have got into the sample instead of one of the four defectives and then you would have accepted. I think you should let the lot through." The answer to such pleading is, "It is true that chance plays a part in the results given by sampling, but these chances are not themselves left to chance. They were precisely calculated when the sampling tables were constructed. In using a particular plan from the tables, we have decided just what risks we can afford to run. To accept when we should reject would mean taking greater risks than we can afford; and it is not more reasonable to accept because the scheme only just rejects, than to reject because it only just accepts. What would you say if I rejected although I had found only three defectives in the sample?"

SECTION 30: ALLOCATION OF AQLs TO DEFECT CLASSES

Throughout this handbook, the defect classifications of critical, major, and minor are used. While these are probably the most commonly used defect classifications, it is possible to use others, and it is possible to use subclassifications of each defect classification. When the classification system has been decided upon for an item, an AQL is assigned, or allocated, to each defect class and/or subclass or to some combination of defect classes and/or subclasses. Following are several illustrations and examples of how AQLs may be allocated to defect classes. Possibly the simplest way to allocate AQLs is to assign each item characteristic to one of the defect classifications. A single AQL is then allocated to each defect class, and all defective item characteristics assigned to the same defect class are counted together. Suppose, for example, that two defect classifications are used, say major and minor, and AQLs are allocated as follows:

Class	AQL
Major	0.40% defective
Minor	1.5% defective

There would then be a separate sampling plan corresponding to each of the AQLs. If a lot passed on each of the two plans, it would be accepted; if it failed on either or both of them, it would be rejected.
Alternative possiblities are:

a. To allow more than two classes, for example:

Class	AQL
Major	0.65% defective
Minor A	1.5% defective
Minor B	4.0% defective

but still accepting or rejecting the lot based upon each class separately.

b. To allocate a separate AQL to each characteristic, possibly with an overriding AQL in addition for all characteristics taken together, or for all characteristics in a class. This method may be valuable where the article is complex and has many independent characteristics to be inspected.

c. To consider the major class by itself but then combine all defects to consider major and minor together. AQLs might be set as, for example:

Class	AQL
Major	1.0% defective
Major + Minor	4.0% defective

While more complicated methods undoubtedly have their place in appropriate circumstances, only the simplest methods will be considered here since the working of a complicated plan can become formidable on the shop floor. Notice that in this illustration the AQL for the major defect classification is smaller than the AQL for the combined major-minor classification. A general rule that should be followed by the responsible authority in assigning AQLs to classes and subclasses of defects is that the AQLs assigned to a class should be at least as great as the largest AQL assigned to any of the subclasses. If the AQLs assigned to the subclasses are all equal then the AQL assigned to the class of combined subclasses of defects should be larger than the subclass AQL.

Example 17: A product has five characteristics to be checked on each article inspected. Characteristics A and B are classified as major, while C,D, and E are minor. Suppose the AQLs are allocated:

Class	AQL
Major	0.65% defective
Minor	2.5% defective

Suppose that for both classes the inspection level is III, and single sampling and normal inspection are to be used with lots of size 900. The code letter is K. The following are the sampling plans:

Class	Sample Size	Acceptance Number	Rejection Number
Major	125	2 defectives	3 defectives
Minor	125	7 defectives	8 defectives

This pattern, the same sample size for each class but different acceptance numbers, is typical and makes the administration of sampling easier, since the same physical sample may be used for each class (provided the inspection is not destructive).

From a particular lot, a sample of 125 might give the following results:

1 item defective in characteristic A only,
1 item defective in characteristics B and D,
2 items defective in characteristic C only,
3 items defective in characteristics C and D.

There are 2 major defectives and 5 minor defectives, in the sample. However, for the purposes of the sampling plan, that is, for the purposes of counting against the major and minor acceptance and rejection numbers, there are two major defectives and six (not five) minor defectives. The difference in the count of minor defectives is the result of the item that has a defect in each the B(major) and the D(minor) characteristics. The lot may be accepted.

Example 18: A product is to be inspected under the following conditions: lot size 500, inspection level II, normal inspection, single sampling. The AQLs are:

Class	AQL
Major	.065% defective
Minor	0.25% defective

The sampling plans are found to be:

Class	Sample Size	Acceptance Number	Rejection Number
Major	200	0 defective	1 defective
Minor	50	0 defective	1 defective

In this situation a sample of 50 should be examined for all types of defects, and then a further sample of 150 for major defects only.

Alternatively, since a sample of 200 is needed anyway, the inspector may decide that it would be as well to inspect this size sample for both classes. He may do this provided the responsible authority approves [9.4]. By using code letter L, the plan for minors becomes:

Sample size	200
Acceptance Number	1
Rejection Number	2

When defects are classified, with separate AQLs for the different classes or groups of classes, then the switching between normal and tightened inspection is done independently for each class, or group of classes, for which an AQL is specified, according to the acceptances or rejections for that particular class or group.

Example 19: The conditions are: lot size 275, inspection level III, single sampling. AQL for majors 1.5% defective. AQL for minors 4.0% defective. Table G shows the hypothetical results and the manner in which the switching is done. So much switching in such a short experience is useful for the sake of an example, but unlikely in real life.

SECTION 31: DOUBLE AND MULTIPLE SAMPLING PLANS

31.1 General. The principles of drawing double or multiple plans from the tables are similar to those for single sampling, but Table III or IV of the master tables is used instead of Table II, or the appropriate part of the page if using the extended tables. If the extended tables are used, care should be taken to see that the correct sample sizes are taken since the tables give only the cumulative sizes. However, the plans all have the feature that successive samples are equal in size to the first sample, and this rule is easily remembered. It should also be remembered that the acceptance and rejection numbers given in the tables are cumulative. That is, the acceptance and rejection numbers given for the third sample, say, of a multiple sampling plan are the maximum defects (defectives) for acceptance and the minimum defects (defectives) for rejection that may be detected in total for the first three samples, not from the third sample alone.

31.2 Changing Plans. Once inspection has begun on a sample from a lot under either a single, or double, or multiple type sampling plan, inspection is to continue with that type of plan until inspection for the lot has been completed. If inspection of a lot begins with a double sampling plan, for example, inspection may not switch to a single sampling plan midway through inspection of either the first or second sample selected from the lot.

Example 20: An item specification calls for inspection at an (MIL-STD-105) AQL of .40% defective. The sample size code letter is P, and a double sampling plan is to be used. The sampling plan for normal inspection is:

	First Sample	Second Sample
Sample Size	500	500
Acceptance Number	3	8
Rejection Number	7	9

The first sample is selected and inspected, and seven defectives are found. The inspector, instead of rejecting the lot according to the rules of the double sampling plan, selects a second sample of 300 units from the lot and says that he will try to have the lot accepted under the single sampling plan equivalent to the above double sampling plan:

AQL	.40%	
Sample Size	800	(=500 + 300)
Acceptance Number	7	
Rejection Number	8	

TABLE G - Twenty lots from a hypothetical inspection process. Inspection level III (See Example 19).

Lot Number	Lot Size	Sample Size	Majors (AQL = 1.5% defective) Ac	Re	Defectives	Disp.	Future Action	Minors (AQL - 4.0% defective) Ac	Re	Defectives	Disp.	Future Action	Lot Disp.
36	275	50	2	3	2	Ac	Cont. normal	5	6	3	Ac	Cont. normal	Ac
37	275	50	2	3	1	Ac	Cont. normal	5	6	4	Ac	Cont. normal	Ac
38	275	50	2	3	3	Re	Cont. normal	5	6	3	Ac	Cont. normal	Re
39	275	50	2	3	2	Ac	Cont. normal	5	6	3	Ac	Cont. normal	Ac
40	275	50	2	3	4	Re	Switch to tightened	5	6	5	Ac	Cont. normal	Re
41	275	50	1	2	2	Re	Cont. tightened	5	6	4	Ac	Cont. normal	Re
42	275	59	1	2	3	Re	Cont. tightened	5	6	8	Re	Cont. normal	Re
43	275	50	1	2	1	Ac	Cont. tightened	5	6	6	Re	Switch to tightened	Re
44	275	50	1	2	1	Ac	Cont. tightened	3	4	5	Re	Cont. tightened	Re
45	275	50	1	2	0	Ac	Cont. tightened	3	4	3	Ac	Cont. tightened	Ac
46	275	50	1	2	0	Ac	Cont. tightened	3	4	5	Re	Cont. tightened	Re
47	275	50	1	2	1	Ac	Restore normal	3	4	2	Ac	Cont. tightened	Ac
48	275	50	2	3	1	Ac	Cont. normal	3	4	2	Ac	Cont. tightened	Ac
49	275	50	2	3	1	Ac	Cont. normal	3	4	1	Ac	Cont. tightened	Ac
50	275	50	2	3	0	Ac	Cont. normal	3	4	0	Ac	Cont. tightened	Ac
51	275	50	2	3	1	Ac	Cont. normal	3	4	2	Ac	Restore normal	Ac
52	275	50	2	3	1	Ac	Cont. normal	5	6	2	Ac	Cont. normal	Ac
53	275	50	2	3	0	Ac	Cont. normal	5	6	1	Ac	Cont. normal	Ac
54	275	50	2	3	2	Ac	Cont. normal	5	6	4	Ac	Cont. normal	Ac
55	275	50	2	3	2	Ac	Cont. normal	5	6	3	Ac	Cont. normal	Ac

Since seven defectives have been found already in the first sample of 500, the inspector hopes to find no defectives in the sample of 300 and thus qualify the lot for acceptance under the above single sampling plan. The customer's quality assurance representative becomes aware of the manufacturer's intention, objects to this proposed violation of the contract between the two parties, pointing out that such a change in the sampling plan would increase the probability of accepting lots at all quality levels, but especially those of undesirable quality.

31.3 O.C. Curves. The extended tables of MIL-STD-105 give both drawings of OC curves and tabulated values from which the drawings were made. The curves apply to single sampling plans, but the curves for double and multiple sampling plans have been matched as closely as practicable [11.1].

31.4 If No Plan Is Available. Where the appropriate single sampling plan has an acceptance number of zero or a sample size of 2, no double or multiple plan is available. The alternative is either to use single sampling or the double or multiple plan for the next larger sample size that is available for the required AQL.

Example 21: If No Plan Is Available. Suppose consideration is being given to the use of a double sampling plan to inspect lots of a product. If the AQL is 0.40 and the code letter is G, an asterisk in Table III-A refers us to a footnote. Either Table II-A may be used in which case the plan would be:

Sample Size	32
Acceptance Number	0
Rejection Number	1

or we may continue down the 0.40 column in Table III-A until we find the double plan under code letter K:

	First	Second	Combined
Sample Size	80	80	160
Acceptance Number	0		1
Rejection Number	2		2

If the extended tables are used the same alternatives will be found.

31.5 Reduced Inspection. For double or multiple sampling with reduced inspection, a result falling in the gap between acceptance and rejection numbers on any sample but the last means that a further sample should be taken, just as for normal or tightened inspection. However, there is also a gap between the acceptance number and rejection number for the final sample. If the total number of defects or defectives falls in this gap, the batch should be accepted but normal inspection restored, as with reduced single sampling [10.1.4].

SECTION 32: AVERAGE SAMPLE SIZE

Table IX gives "average sample size" curves for double and multiple sampling. These curves may be used to decide whether or not the reduced amount of sampling from the use of double or multiple sampling instead of single sampling will be sufficient to be worthwhile [11.5]. The curves are classified by the value of the single sampling acceptance number, and are necessarily approximate to some extent, since they cannot apply exactly to all the different plans given. However, they apply accurately enough for their purpose. The horizontal scale of each curve is in units of "n times proportion defective" where n is the sample size of the relevant single sampling plan. In any particular case, this scale may be divided by n to get a scale of proportion defective. The vertical scale is in terms of the same value of n. The line at the top of each diagram therefore represents the single sample size, and the efficiency of the double and multiple plans may be judged from their curves in relation to this top line. (The efficiency of the double and multiple plans is the ratio of the average sample size of these plans to the sample size for the single sampling plan with the same AQL.) It should be noted that in operating sampling inspection it is expected that normal inspection with the submitted quality better than the AQL will be in force most of the time. In this case, the most relevant parts of these curves are the sections to the left of the arrows on the base line. Those diagrams that have no arrows refer to acceptance numbers used only in tightened inspection. When the single sampling plan has an acceptance number of 1, the multiple plan is, much of the time, less efficient than the double plan. It was impossible to avoid this regrettable feature without losing other valuable features of the tables. In these circumstances, double sampling is to be preferred unless there is some good reason other than the average sample size for desiring to use multiple sampling. Table IX assumes that curtailment of inspection, as described in Section 13, is not used (see Section 34).

Example 22: <u>Comparison for Single, Double, and Multiple Plans</u>. The single sampling plan for code letter K and AQL 2.5% defective is in use, namely:

Sample Size	125
Acceptance Number	7
Rejection Number	8

Consideration is being given to changing to double or multiple sampling. The appropriate diagram in Table IX is that labelled c = 7, which is the acceptance number. If so desired, the bottom scale may be divided by 125, the sample size, and multiplied by 100 to obtain a scale of % defective. The figures 3, 6, 9, and 12 then become 2.4%, 4.8%, 7.2%, and 9.6% defective.

Usually, however, it is not necessary to do this to discover what it is wished to know, the relative effect of single, double, and multiple sampling on the required amount of inspection.

Similarly, the scale on the left-hand side can be read as 0.25, 0.5, 0.75 of 125 is desired.

From the Table IX diagram it can be seen that the average sample size for the double sampling plan will range from 80 to about 90 when the process average is at the AQL or better and from 32 to about 75 for the multiple sampling plan over the same range of product quality. Thus, both the double and the multiple sampling plans significantly reduce the amount of sampling below that required by the single sampling plan. However, other factors must also be considered before a decision can be made about which type of sampling plan to use in this situation. Section 33 discusses some of these factors.

Looking at the curves of Table IX it will be seen:

a) that the double plan almost always has a smaller average size than the single one, and the multiple plan almost always a smaller average than the double;

b) that if the quality is perfect, the double sample size is about two-thirds of the single, the multiple about a quarter of the single;

c) that at the AQL these fractions have risen to about seven-tenths and six-tenths respectively;

d) that the maximum average value of the double is a little over nine-tenths of the single, the maximum average value of the multiple a little over eight-tenths of the single.

SECTION 33: SELECTING A SINGLE, DOUBLE, OR MULTIPLE SAMPLING PLAN

Since, at a given AQL and sample size code letter, each of the three types of sampling plans in Tables II, III, and IV of the standard offer nearly equal protection (OC curves are nearly equal), the producer may select which type he will use in a particular application. The type of plan that he chooses will be influenced by several factors. One of those factors, average sample size, was discussed in Section 32. Among other factors to be considered are:

a. The cost of administering the double or multiple sampling plan compared to the cost of administering the single sampling plan. Usually the cost of administering a multiple sampling plan is the greatest, and the cost of administering a single sampling plan the least.

b. The need for quick and reliable estimates of the process average. Since, over the long run, fewer sample units will be tested under double or multiple sampling than under single sampling, and since, therefore, double or multiple sampling plans would provide less data from which to compute the estimates, single sampling may be the most desirable method during the time those estimates are needed.

c. The availability of inspection personnel and facilities. In some situations, personnel who perform inspection have no other duties. In such cases, reducing the amount of inspection by changing from a single sampling plan to a double or multiple sampling plan may simply leave inspection personnel with idle time and accomplish no real saving. When this happens, it might be just as well to use a single sampling plan, not simply to reduce the inspectors' idle time, but also to obtain additional production data.

In other situations the need for inspection personnel and/or inspection facilities may be expanding rapidly. In order to gain time for hiring and training new inspection personnel or for building new inspection facilities, double or multiple sampling plans may be employed at least temporarily to take advantage of the smaller sampling requirements.

SECTION 34: CURTAILMENT OF INSPECTION

Although inspection of the entire sample may not be required in the general attribute lot sampling plan situation (Section 13 of this handbook), when inspection is being done under the provisions of MIL-STD-105, all of each sample must be inspected [10.1.1, 10.1.2].

SECTION 35: LIMITING QUALITY AND THE ISOLATED LOT

35.1 General. The most frequent use of the sampling plans in MIL-STD-105 is in procurement actions where the producer attempts to furnish the consumer with a product that satisfies some specified quality requirements. In such situations, it is frequently specified that attribute inspection of the product is performed by the producer with a sample being selected at random from each lot and inspected.

35.2 Producer's Risk. The sampling plan in Tables II through IV of MIL-STD-105 were designed with consideration only for the risk to the supplier. The sample size, the acceptance number, and the rejection number have been chosen to provide a high probability of lot acceptance (Pa) when the quality of the lot is at the AQL or better. The producer's risk is the probability that an acceptable lot will be rejected when lot quality is at some relatively good level, usually equal in value to the AQL. The producer's risk at all quality levels for each plan can be found from the OC curves, Tables X-A through X-R.

35.3 Consumer's Risk. From Table X-A through Table X-R of MIL-STD-105 it may be seen that lots containing a high percent defective (or defects per hundred units) have a low probability of acceptance (Pa), or a relatively high probability of rejection. For isolated lots (see 6.7 and 10.3), a low probability of accepting lots with a high percent defective may be of primary concern. When this requirement is stated, it is usually in terms of the limiting quality which is the worst quality that the consumer is willing to accept.

A low probability of acceptance must be associated with this requirement. This low probability of acceptance is called the consumer's risk. Tables VI and VII of MIL-STD-105 give values of LQ which may be interpreted as undesirable quality for the more commonly used consumer's risks of ten percent and five percent, respectively. While these tables were developed using single sampling plan computations, the results closely approximate results for double and multiple sampling plans with the same AQL.

35.4 Isolated Lots. In most of the sampling procedures of MIL-STD-105 the assumption is made that units of product are produced continuously and are grouped into numerous consecutive lots. Sampling plans for such a situation are usually geared toward protecting the producer from the rejection of lots with quality better than the AQL. When product quality deteriorates sufficiently, inspection shifts to a tightened sampling plan to provide greater protection to the consumer against accepting a lot of low quality. However, in certain situations, only a few (isolated) lots of product are produced. It is no longer satisfactory to the consumer, in this situation, to use sampling plans based upon the producer's risk because there is little or no time for detection of product deterioration and a subsequent shift to a tightened sampling plan. Hence, it is desirable, in the isolated lot(s) situation, to begin inspection with a sampling plan that reduces the consumer's risk of accepting a lot with product quality worse than the Limiting Quality.

35.5 Selecting LQ Sampling Plans. MIL-STD-105 provides sampling procedures for assuring the consumer that lots of quality equal to the limiting quality (LQ) or worse will be accepted with low probability. The provisions of the standard allow for situations in which, along with the LQ, either (a) the AQL has been specified or (b) the sample size code letter has been specified.

35.5.1 AQL Specified. In order to obtain an LQ sampling plan in which the AQL has also been specified:

a. Select the appropriate LQ Table. The selection will be Table VI-A, VI-B, VII-A, or VII-B depending upon the specified consumer's risk at the LQ and the method for expressing nonconformities.

b. Enter the selected table at the column for the specified AQL.

c. Read down the column until the first LQ is found which is less than or equal to the specified LQ.

d. Obtain the sample size code letter from the left-hand column of the table.

e. Obtain acceptance/rejection numbers from Table IIA, IIIA, IVA, depending upon whether single, double or multiple sampling is being done.

Example 23: LQ Sampling Plan with AQL Specified. The consumer has specified an AQL of 4.0% defective for his product. He has also required that the lot should contain more than 10% defective (LQ=10%) no more than 5% of the time (consumer risk = 5%). The appropriate single sampling plan, normal inspection, is determined as follows:

a. Turn to Table VII-A (consumer risk = P_a = 5% and the expression of nonconformance is percent defective) in MIL-STD-105.

b. Enter the table at the column headed 4.0.

c. Read down the column to 9.6, the first LQ value below 10.

d. Find the sample size code letter and the sample size for the sampling plan at the left of the row in which LQ=9.6 is found. The sample size code letter is M and the sample size is 315.

e. Find the accept/reject numbers, 21/22, in Table II-A.

35.5.2 <u>Sample Size Code Letter Specified</u>. In order to obtain a sampling plan from MIL-STD-105 for which the LQ and the sample size code letter (or sample size) have been specified:

a. Obtain the sample size code letter from Table I based on the lot size and the specified inspection level.

b. Select the appropriate LQ Table. The selection will be Table VI-A, VI-B, VII-A or VII-B depending upon the specified P_a at the LQ and the method for expressing nonconformity.

c. Enter the selected table at the two left-hand columns. Read down the columns until the specified sample size or sample size code letter is found.

d. Read along the row in which the sample size code letter is found until the last value is found that is less than or equal to the specified LQ.

e. Obtain the AQL of the sampling plan at the top of the column in which the number in d. was found.

f. Obtain the acceptance/rejection numbers from Table II-A, III-A or IV-A depending on whether single, double or multiple sampling is being done.

Example 24: <u>LQ Sampling Plan with Sample Size Code Letter Specified</u>.

A consumer has received shipment of 3600 bottles of glue. Each empty bottle is supposed to weigh 2 ounces and contain 16 ounces of glue for a gross weight of 18 ounces. The supplier is suspected of short weights. The consumer decided he is willing to accept the shipment if there is no more than a 10% chance (consumer's risk = 10%) that the shipment contains no more than 5% defectives (LQ value = 5.0%), where a defective is defined as any bottle of glue having a gross weight less than 17 ounces. The single sampling plan, using normal inspection, may be obtained from MIL-STD-105 as follows:

a. From Table I, since the lot size is 3600 units and the use of general inspection level II is assumed, the sample size code letter is L.

b. Since the consumer's risk is not to exceed 10% and since nonconformance is expressed in terms of percent defective, Table VI-A is used to obtain the AQL.

c. In the row of Table VI-A that is labeled with code letter L, 4.6 is the largest value less than the specified LQ of 5%. The AQL is 1.0%, seen at the head of the column in which 4.6 is found.

d. The sample size is therefore 200 units, the acceptance number is 5 units, and the rejection number is 6 units, as found in Table II-A based on sample size code letter L and an AQL value of 1.0% defective.

SECTION 36: THE AOQL TABLE

36.1 Computing the AOQL. Tables V-A and V-B give AOQL factors for the normal and tightened single sampling plans. These factors will also give the approximate AOQLs for the equivalent double and multiple plans. A footnote to the tables says that in order to obtain the AOQL for a sampling plan, the tabular value should be multiplied by

$$1 - \frac{\text{sample size}}{\text{batch size}}$$

If the sample is only a small proportion of the lot, this calculation makes little difference, and the tabular values may be used as they stand. But if the sample is a large proportion of the lot, this multiplication should not be forgotten. A study of Table V-B will show that, except in the top diagonal (where the acceptance number is 0), the AOQL for tightened inspection is always close to the AQL. If it is desired to have this relationship between AQL and AOQL for tightened inspection, then use should be made of the option of using the plans with an acceptance number of 1 instead of those with an acceptance number of 0 [9.4].

Example 25: Using Table V-A. For a lot size of 400, an AQL of 4.0% defective, and inspection level II, the code letter is found to be H. For normal inspection, the AOQL is found from Table V-A as:

$$6.3 \left[1 - \frac{50}{400}\right] \text{ \% defective} = 5.5\text{\% defective}$$

36.2 Caution. It must be remembered that MIL-STD-105 is designed for production runs which are at least several lots in length. During such a production run, it is to be expected that both normal and tightened inspection (and perhaps reduced inspection as well) will be performed. Since switching must be expected, the method for computing the AOQL must take that switching into account. However, the method for computing the AOQL in MIL-STD-105 does not take switching into account, and therefore, any AOQL computed by that method will not truly reflect the AOQL of the sampling scheme. Despite this fact, Tables V-A and V-B can be useful in the following ways. First, in the long run situation, Table V-A can furnish an upper bound on the true AOQL when switching is only between tightened and normal inspection. Second, the tables can be properly applied in the isolated lot situation in which switching between normal, tightened, and reduced inspection is not possible.

SECTION 37: SELECTING INSPECTION LEVELS

37.1 General. MIL-STD-105 provides for three general inspection levels and four special inspection levels. These seven levels permit the user to balance the cost of inspection against the amount of protection required.

37.2 Selection of Inspection Levels. General inspection levels I to III are commonly used for nondestructive type inspection. Special levels S-1 to S-4 are commonly used for destructive or expensive type inspection wherein small size samples are appropriate. The responsible authority should analyze as many of the following factors as the situation calls for before specifying an inspection level. The aim of the analysis should be to determine the inspection level which optimizes the cost-risk relationship. The analysis may include, but not be limited to the following:

a. The operating characteristic (OC) curves to evaluate the technical properties of the various plans.

b. The supplier's risk and discrimination afforded by the various inspection levels.

c. Knowledge of the production process.

d. Process capability and quality performance history.

e. Item complexity.

f. Cost and importance of examination or test, particularly when testing is expensive, time consuming, or destructive.

g. Importance of the quality characteristics being examined, that is, critical, major, and so forth.

h. Analysis of consumer's risk.

37.3 More Than One Inspection Level. At the commencement of production, or when the records of past production are not available, it may be desirable to use 100% inspection for a period to establish the quality capability of the production process. Alternatively, if a sampling procedure is to be used, the highest inspection level that is either practicable or economical for the initial production run may be selected. The responsible authority may then specify a lower inspection level if records indicate that product quality has been consistently good and that the consumer's risk at this new level is acceptable. It should be noted that the choice of a lower inspection level increases the consumer's risk at the LQ to a greater extent than it affects the probability of acceptance when the submitted quality is equal to the AQL or better. Another use for more than one inspection level occurs when the tables are being applied to the same product by two different inspection organizations, such as a main contractor and a subcontractor or a manufacturer and a government inspectorate. The same AQL should be used by both and applied to the same features, but the producer's inspector may be required to use a higher inspection level than that being used by the verification inspector (see para 17.1 and 17.4). Other sampling procedures are available for this type of situation but they are outside the scope of this guide.

37.4 Special Inspection Levels. Special inspection levels S-1, S-2, S-3, and S-4 may be used when expensive or destructive inspection and large sampling risks can or must be tolerated. These levels may also be considered appropriate when repetitive processes (screw machines, stapling, bolting operations, etc.) are performed by a quality supplier. The special inspection levels are attractive in these situations because they require sample sizes that are smaller than those required by the general inspection levels. The special inspection levels provide for larger sample sizes when increasing from S-1 to S-4.

Example 26: Considerations in Selecting an Inspection Level. An AQL of 1.5% defective has been chosen, and it is desired to have at least an 80% chance of rejecting a 6% defective lot if such a lot should be offered while normal inspection is in operation. Looking at the O.C. curves in the extended tables it is found that code letters A to J, for AQL 1.5, all fail to meet the requirement. Code letter K almost meets it precisely -- in fact the chance of rejecting at 6% defective is slightly less than 80%, but it is close enough for most practical purposes. Code letters L-P more than meet the requirement. Suppose the lot size normally to be expected is 1,000. Then inspection level III can be specified, since this will give code letter K for a 1,000 lot size. If at a later stage the lot size is increased, the specified inspection level may call for code letters later than K in the alphabet. This is satisfactory, as it means that the increased lot size is being put to good use in reducing the risks of accepting bad lots or rejecting good lots. From this point of view, there is no need to put an upper limit on the batch size. On the other hand, a lower limit on lot size of 501 should be set, if possible, in order to insure that the AQL/LQ requirement is met. However, it is quite often not possible or desirable to set such a limit. Among the factors which might prevent setting limits on lot size are the requirements of homogeneity within a lot (para 6.4) or organizational policies which state that the production within a specified time period must comprise a single lot.

APPENDIX A: READING AND REFERENCE MATERIAL

There are many fine reference books and articles that provide additional guidance on the basic concepts, mathematical theory, methods, procedures, and practical applications of sampling inspection. No attempt is made to list all these references. Omission of any specific reference does not imply disapproval. The following references are a partial list and are arranged alphabetically by author:

BOOKS:

1. Bowker, A.H., and Lieberman, G.L., "Engineering Statistics," 2d Ed., Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1972.

2. Burr, Irving W., "Engineering Statistics and Quality Control," McGraw-Hill Book Co., Inc., New York, 1953.

3. Burr, Irving W., "Statistical Quality Control Methods," Marcel Dekker, Inc., New York, 1976.

4. Cowden, Dudley J., "Statistical Methods in Quality Control," Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1957.

5. Dixon, W. J., and Massey, F.J., Jr., "Introduction to Statistical Analysis," 3rd Ed., John Wiley and Sons, Inc., New York, 1969.

6. Dodge, H.F., and Romig, H. G., "Sampling Inspection Tables -- Single and Double Sampling," 2d Ed., John Wiley and Sons, Inc., New York, 1959.

7. Duncan, A. J., "Quality Control and Industrial Statistics," 4th Ed., Richard D. Irwin, Inc., Homewood, Illinois, 1974.

8. Grant, E. L. and Leavenworth, R.L., "Statistical Quality Control," 5th Ed., McGraw-Hill Book Co., Inc., New York, 1980.

9. Hoel, P. G., "Introduction to Mathematical Statistics," 2d Ed., John Wiley and Sons, Inc., New York, 1954.

10. Juran, J. M. (ed.), "Quality Control Handbook," 3d Ed., McGraw-Hill Book Co., Inc., New York, 1974.

11. Rand Corporation, "A Million Random Digits with 100,000 Normal Deviates," Glencoe Free Press Division of the Macmillan Company, New York, 1955.

12. Wald, A., "Sequential Analysis," John Wiley and Sons, Inc., New York, 1947.

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13. Brugger, Richard M., "A Simplification of Skip-Lot Procedure Formulation," Journal of Quality Technology, Vol. 7, No. 4, October, 1975, pp 165-167.

14. Dodge, H.F., "Notes on the Evolution of Acceptance Sampling Plans, Part I, "Journal of Quality Technology, Vol. 1, No. 2, April 1969, pp 77-88.

15. Dodge, H.F., "Notes on the Evolution of Acceptance Sampling Plan Part II," Journal of Quality Technology, Vol. 1, No. 3, July 1969, pp 155-162.

16. Dodge, H.F., "Notes on the Evolution of Acceptance Sampling Plans, Part III," Journal of Quality Technology, Vol. 1, No. 4, October 1969, pp 225-232.

17. Dodge, H.F., "Notes on the Evolution of Acceptance Sampling Plans, Part IV," Journal of Quality Technology, Vol. 2, No. 1, January 1969, pp 1-8.

18. Dodge, H.F, "Skip-Lot Sampling Plans," Industrial Quality Control Vol. 11, No. 5, February, 1955, pp 3-5.

19. Stephens, K.S., and Larson, K.E., "An Evaluation of the MIL-STD-105 System of Sampling Plans," Industrial Quality Control, Vol. 23, No. 7, January, 1967.

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20. Askin, Aloise, and Guthrie, Donald, Technical Report No. 14, "A Biased Estimate of the Process Average," 1954, Stanford University, Stanford, California, July 23, 1954.

21. Dodge, H.F., Technical Report No. 10, "A General Procedure for Sampling Inspection by Attributes - based on the AQL Concept," Rutgers - The State University, New Brunswick, New Jersey, December 15, 1959.

STANDARDS

22. ________________ MIL-STD-105D, Sampling Procedures and Tables for Inspection by Attributes; 29 April 1963; Commander, US Army Armament Research and Development Command, ATTN: DRDAR-TST-S, Dover, NJ 07801.

23. ________________ MIL-STD-109B, Quality Assurance Terms and Definitions; 4 April 1969; Commander, Naval Sea Systems Command, DOD Standardization Program and Documents Branch, SEA 3112, Washington, DC 20362 (SH)-5.

24. ________________ ANSI/ASQC A1-1978, Definitions, Symbols, Formulas and Tables for Control Charts; 1978, Milwaukee.

25. ____________________ ANSI/ASQC A2-1978, Terms, Symbols and Definitions for Acceptance Sampling; 1978; Milwaukee.

26. ____________________ ANSI/ASQC A3-1978, Quality Systems Terminology; 1978, Milwaukee.

27. ____________________ International Standard ISO 2859-1974/Addendum 1; General Information on Sampling Inspection, and Guide to the Use of the ISO 2859 Tables; 1 November 1977; ANSI, 1430 Broadway, New York, New York 10018.

28. ____________________ MIL-STD-414, Sampling Procedures and Tables for Inspection by Variables for Percent Defective; 11 Juny 1957; Office of the Assistant Secretary of Defense (Supply and Logistics), Washington, DC.

29. ____________________ MIL-STD-781C, Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution; 21 October 1977; Naval Electronics Systems Command, Defense Standardization Program Branch, Department of the Navy, Washington, DC 20300.

30. ____________________ MIL-STD-1235B, Single and Multi-level Continuous Sampling Procedures and Tables for Inspection by Attributes; 10 December 1981; US Army Armament Research and Development Command, ATTN: DRDAR-TST-S, Dover, NJ 07801.

APPENDIX B: OC FORMULAS

Although MIL-STD-105 provides a large number of attribute lot sampling plans that cover a wide range of needs, it is sometimes necessary to construct a sampling plan that is not given in the standard. OC curves for such sampling plans may be constructed using the formulas given below. When sampling from a lot of discrete units to inspect for defectives, the ideal distribution function for constructing the OC formula is the hypergeometric distribution. However, when lot size is sufficiently larger than the sample size, the binomial distribution offers a good approximation to the hypergeometric distribution and is easier to calculate. Although it offers these advantages, the binomial distribution itself becomes lengthy to calculate as the acceptance number increases. If the lot percent defective is less than 10% and the acceptance number is not less than 15, this lengthy calculation can be reduced by using the Poisson distribution as an approximation to the binomial distribution. (The method of computing OC values in MIL-STD-105 is given at the bottom of the first page of each Table X-A through Table X-R.) Specific recommendations on lot size and sample size ranges to use in order for the above approximations to be good are shown in the following table of formulas. The Poisson distribution should be used in all cases when constructing a sampling plan to inspect for defects. For each of these distributions, the probability of accepting the lot or batch, P_a, is plotted against p, the population fraction defective, to obtain the OC curve. In the case of the hypergeometric distribution, p=D/N (where D is the number of defectives in the lot and N is the lot size) and takes on only the N+1 possible values of D instead of all real values between 0 and 1. Hence, a hypergeometric OC curve is not a curve at all, but a series of spikes protruding from the horizontal axis to a height of $P_a(p)$. It should also be pointed out that the horizontal axis need not be measured in terms of p, as it is customarily for the continuous binomial and Poisson OC curves, but can also be measured in terms of D, the number of defectives in the lot.

TABLE OF OPERATING CHARACTERISTIC (OC) FORMULAS

Distribution	Probability Density Function	Recommended Conditions for Use
Hypergeometric	$P(x)=\dfrac{\binom{D}{x}\binom{N-D}{n-x}}{\binom{N}{n}}$	$N\leq 8n$
	where N= lot size D= number of defects in lot n= sample size x= number of defects in sample P(x)= Probability that a sample will have x defectives when the sample is of size n and is selected at random from a lot of size N with D defectives.	
Binomial	$P(x)=\binom{n}{x}p^{x}(1-p)^{n-x}$	$N>8n$
	where p= population fraction defective, $0\leq p\leq 1$. All others same as for hypergeometric.	
Poisson	$P(x)=\dfrac{(np)\ e^{-np}}{x!}$	$N>8n$ $n>15$ $p\leq .10$
	where p= population fraction defective, $0\leq p\leq 1$ or p= average defects per unit, $0\leq p<\infty$	

OC FORMULAS

Single Sampling

$$P_a=\sum_{x=0}^{c}P(x)$$

where P_a = probability of lot acceptance
c= acceptance number of the sampling plan
P(x)= hypergeometric, binomial, or Poisson probability density function

Double Sampling

$$P_a=\sum_{x=0}^{c_1}P(x)+\sum_{x=c_1+1}^{r_1-1}\left[P(x)\sum_{j=0}^{c_2-x}P(j)\right]$$

where c_1= acceptance number for first sample
r_1= rejection number for first sample
c_2= acceptance number for second sample (defects or defectives in first and second samples must not exceed this number)
j= number of defects in second sample

Example B-1. Single Sampling Plan. A sample of size n=12 is to be drawn from a lot of size 100. Since the lot size is over eight times the sample size, the binomial distribution function is used to construct the OC curve of the sampling plan. The acceptance number is two: N=100, n=12, c=2.

$$P_a = \sum_{x=0}^{2} \binom{12}{x} p^x (1-p)^{12-x} = (1-p)^{12} + 12p\ (1-p)^{11} + 66p^2(1-p)^{10}.$$

$$\text{At } p=.06, P_a = (1-.06)^{12} + 12(.06)(1-.06)^{11} + 66(.06)^2(1-.06)^{10} = .9684$$

Example B-2. Double Sampling Plan. A double sampling plan is used to inspect a lot of size 200. The size of the first sample is eight (n_1=8); the size of the second sample is six (n_2=6); the acceptance number for the first sample is one (c_1=1); the rejection number for the first sample is four (r_1=4); and the acceptance number for the second sample is four (c_2=4). The Poisson distribution is used to calculate the OC curve.

$$P_a = \sum_{x=0}^{1} \frac{(8p)^x e^{-8p}}{x!} + \sum_{x=2}^{3} \left[\frac{(8p)^x e^{-8p}}{x!} \sum_{j=0}^{4-x} \frac{(6p)^j e^{-6p}}{j!} \right]$$

$$= e^{-8p}[1+8p] + e^{-8p} \left[\frac{(8p)^2}{2!} \left\{ 1+6p + \frac{(6p)^2}{2!} \right\} e^{-6p} + \frac{(8p)^3}{3!} \{ 1+6p \} e^{-6p} \right]$$

At p= .08,

$$P_a = e^{-8(.08)}[1+8(.08)] + e^{-8(.08)} \left\{ \frac{[8(.08)]^2}{2} \left\{ 1+[6(.08)] + \frac{[6(.08)]^2}{2} \right\} e^{-6(.08)} + \frac{[8(.08)]^3}{6} \{ 1+6(.08) \} e^{-6(.08)} \right]$$

$$= .5273\ [1.64] + .5273[.2048\ \{1.5952\}\ .6188 + .0437\ \{1.48\}\ .6188]$$

$$= .9925$$

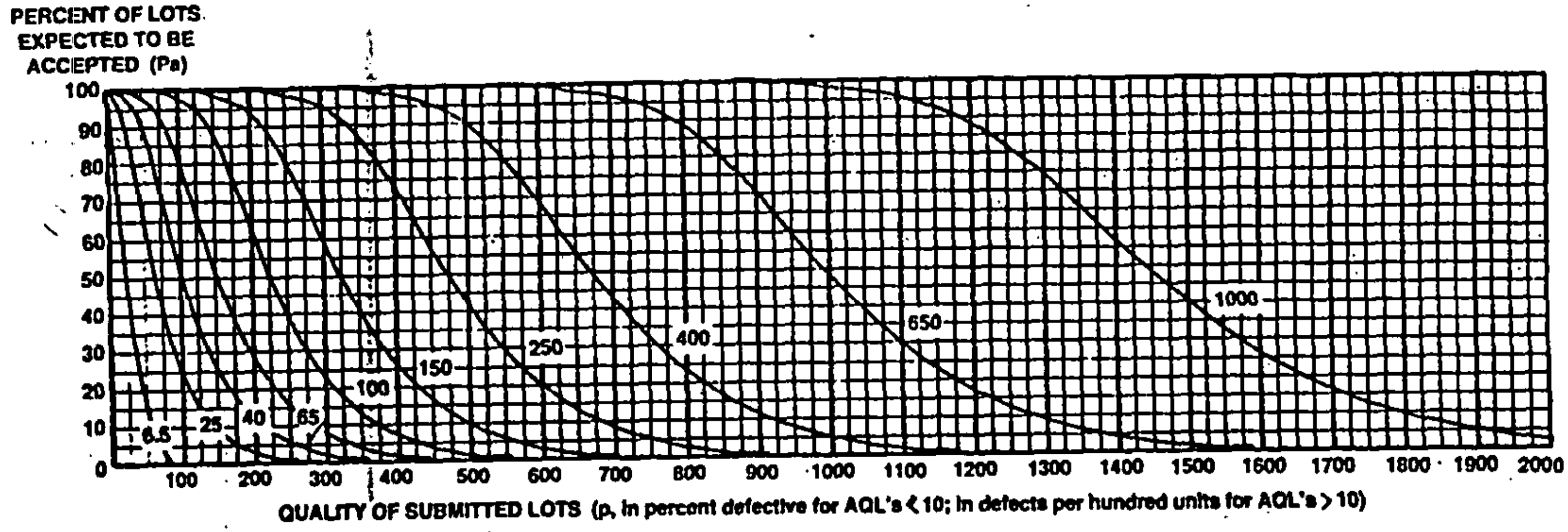
The above examples are given solely to illustrate the computation of various types of OC curves. They are not given, especially in the case of Example B-2, to illustrate a well constructed sampling plan.

APPENDIX C: NORMAL-TIGHTENED OC CURVES AND TABLES FOR MIL-STD-105

This appendix provides OC curves and tables for the normal-tightened sampling schemes that are required by MIL-STD-105 (see Section 26). OC curves and tables for normal-tightened-reduced sampling schemes have not been provided here because MIL-STD-105 does not require reduced sampling. The tables and charts presented here are patterned after Charts A through R and Tables X-A-1 through X-R-1 in MIL-STD-105. Tables which give acceptance, retest, and rejection numbers for each sampling scheme are not given here since such tables would simply repeat information already included in MIL-STD-105. The OC charts and tables given here assume that if ten consecutive lots come under tightened inspection, inspection is suspended, action is taken to improve product quality, and inspection is resumed under tightened inspection (see Section 26.4).

TABLE AND CHART C-A FOR SAMPLE SIZE CODE LETTER: A

CHART C-A - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

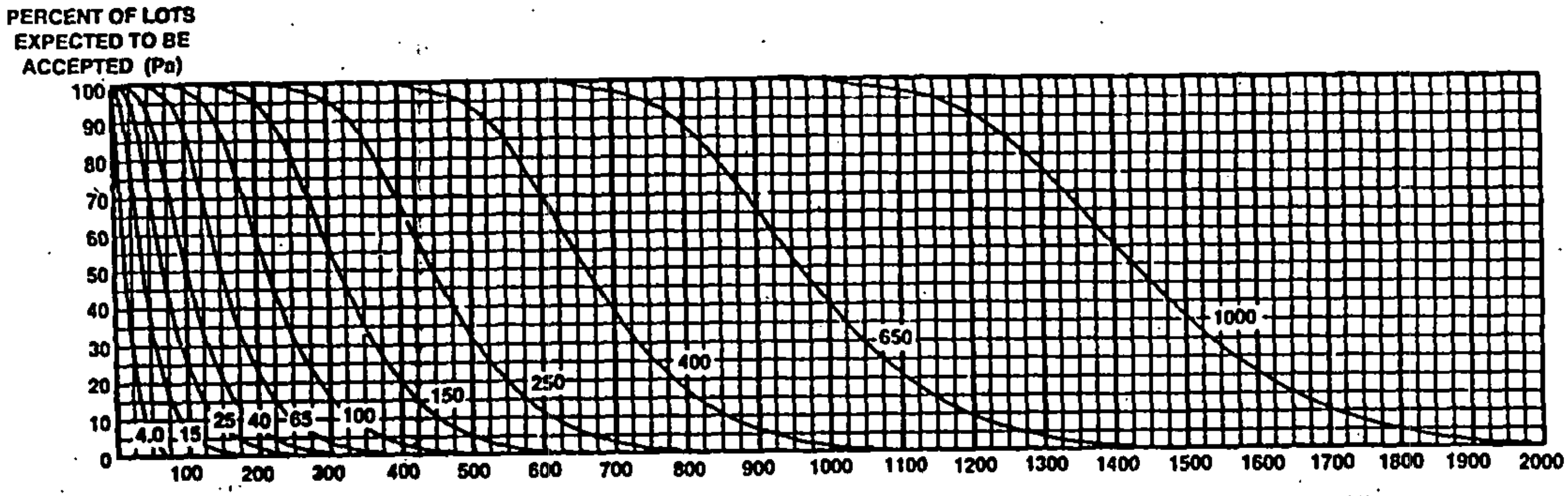
TABLE C-A TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS										
	6.5	6.5	25	40	65	100	150	250	400	650	1000
	p(percent defective)	p(defects per hundred units)									
99.0	0.501	0.502	7.42	21.7	41.1	88.8	145	238	374	628	978
95.0	2.48	2.51	17.3	38.7	66.1	125	193	303	457	735	1113
90.0	4.81	4.93	24.8	49.3	81.2	143	218	336	500	789	1182
75.0	11.30	12.0	40.3	70.0	109	177	262	394	574	877	1295
50.0	23.2	26.4	64.7	103	152	225	323	472	670	992	1439
25.0	40.0	51.2	100	152	212	293	405	572	791	1134	1612
10.0	57.0	84.5	144	213	283	373	498	681	918	1284	1790
5.0	66.8	110	177	257	333	429	563	755	1002	1382	1905
1.0	82.3	173	254	358	441	554	700	909	1178	1585	2137

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-B FOR SAMPLE SIZE CODE LETTER: B

CHART C-B - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's ≤10; in defects per hundred units for AQL's >10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

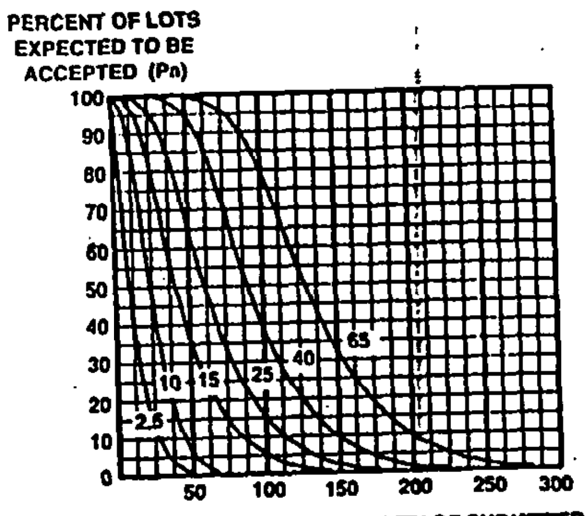
TABLE C-B- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

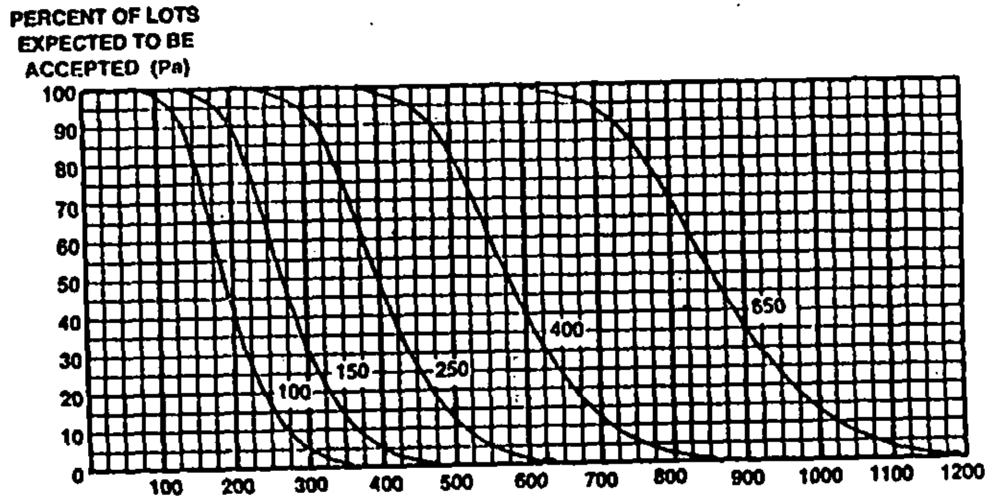
Pa	ACCEPTABLE QUALITY LEVELS											
	4.0	4.0	15	25	40	65	100	150	250	400	650	1000
	p(percent defective)	p(defects per hundred units)										
99.0	0.33	0.34	4.94	14.5	27.4	59.2	96.6	159	249	419	651	1029
95.0	1.65	1.66	11.4	25.8	44.1	83.0	129	202	305	490	742	1148
90.0	3.17	3.22	18.2	32.9	54.1	95.6	146	224	334	526	788	1206
75.0	7.35	7.63	25.7	46.6	73.0	118	175	263	382	585	864	1303
50.0	15.2	16.5	40.6	68.5	101	150	216	314	447	681	959	1425
25.0	27.2	31.7	62.6	101	141	195	270	381	527	756	1075	1567
10.0	40.8	52.4	90.2	142	189	248	332	454	612	856	1194	1709
5.0	49.7	68.7	111	172	222	286	375	503	668	922	1270	1800
1.0	66.5	109	163	238	294	369	467	606	784	1056	1425	1981

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-C FOR SAMPLE SIZE CODE LETTER: C

CHART C-C - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES





QUALITY OF SUBMITTED LOTS (p, In percent defective for AQL's ≤ 10; In defects per hundred units for AQL's > 10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

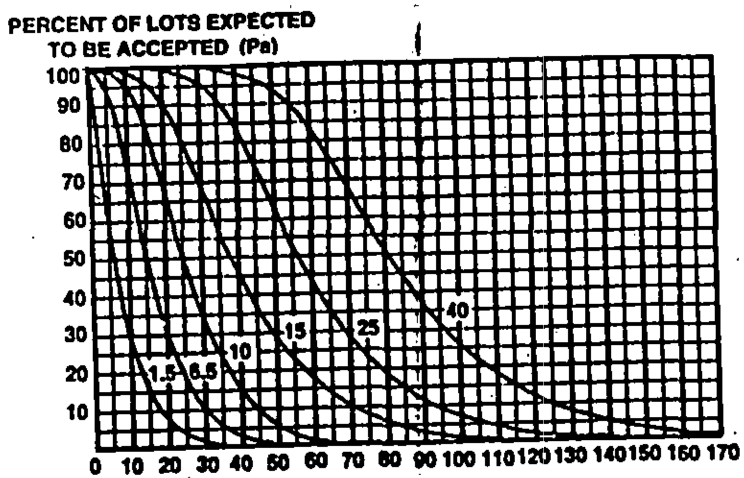
TABLE C-C- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

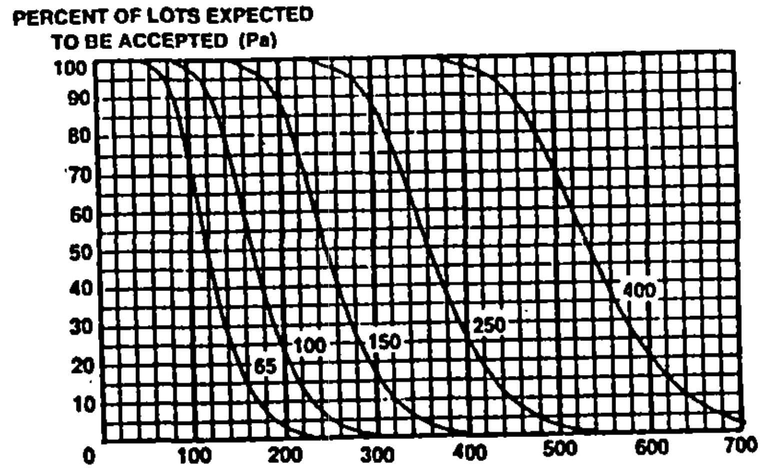
Pa	ACCEPTABLE QUALITY LEVELS												
	2.5	10	2.5	10	15	25	40	65	100	150	250	400	650
	p(percent defective)		p(defects per hundred units)										
99.0	0.20	3.26	0.20	2.97	8.68	16.4	35.5	58.0	95.3	149	251	390	617
95.0	1.00	7.39	1.00	6.90	15.5	26.5	49.8	77.2	121	183	294	445	688
90.0	1.93	10.3	1.95	9.79	19.7	32.5	57.4	87.3	135	200	316	473	724
75.0	4.56	15.8	4.88	15.7	28.0	43.8	70.9	105	158	229	351	518	782
50.0	9.85	23.8	10.2	24.9	41.1	60.8	90.1	129	189	268	397	576	855
25.0	17.8	34.3	19.6	38.5	60.8	84.9	117	162	229	316	453	645	940
10.0	27.8	45.5	32.3	55.4	85.2	113	149	199	272	367	513	716	1026
5.0	34.5	52.7	42.3	68.2	103	133	172	225	302	401	553	762	1080
1.0	48.8	65.7	68.9	98.9	143	177	222	280	384	470	634	855	1188

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-D FOR SAMPLE SIZE CODE LETTER: D

CHART C-D - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES





QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's < 10; in defects per hundred units for AQL's > 10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

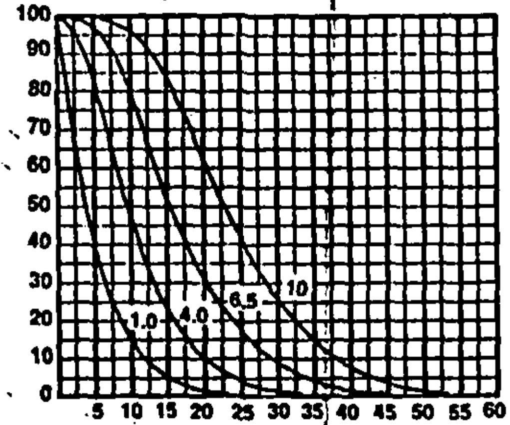
TABLE C-D-TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

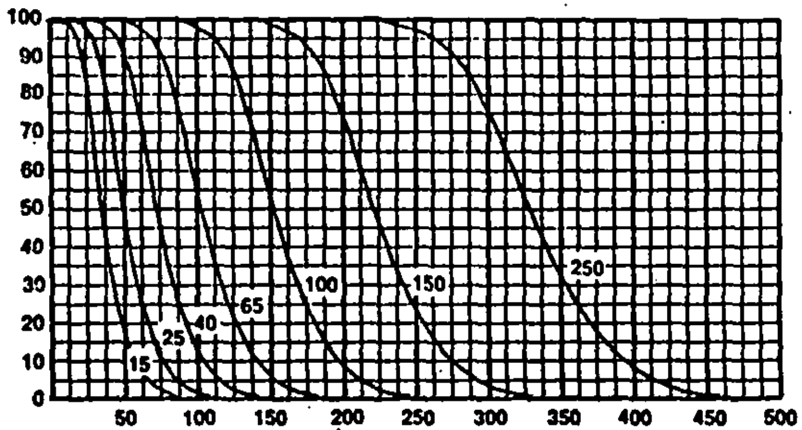
Pa	ACCEPTABLE QUALITY LEVELS													
	1.5	6.5	10	1.5	6.5	10	15	25	40	65	100	150	250	400
	p(percent defective)			p(defects per hundred units)										
99.0	0.125	1.98	6.05	0.125	1.85	5.42	10.3	22.2	38.2	59.6	93.4	157	244	386
95.0	0.622	4.49	10.5	0.624	4.30	9.68	16.5	31.1	48.3	75.7	114	164	278	430
90.0	1.21	6.28	13.1	1.22	6.10	12.3	20.3	35.9	54.6	84.1	125	197	296	452
75.0	2.85	9.79	17.9	2.89	9.74	17.5	27.4	44.3	65.6	98.5	143	219	324	489
50.0	6.09	15.0	24.9	6.28	15.4	25.7	38.0	58.3	80.8	118	168	248	360	534
25.0	11.4	22.2	34.3	12.1	23.8	38.0	53.0	73.1	101	143	198	283	403	588
10.0	18.1	30.4	44.5	20.0	34.3	53.2	70.7	93.2	125	170	230	321	448	641
5.0	23.0	36.0	51.0	26.2	42.3	64.3	83.1	107	141	189	251	346	476	675
1.0	33.9	48.0	63.0	41.5	61.5	89.1	110	138	175	227	294	398	534	743

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-E FOR SAMPLE SIZE CODE LETTER: E

CHART C-E - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES





QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's ≤10; in defects per hundred units for AQL's >10)

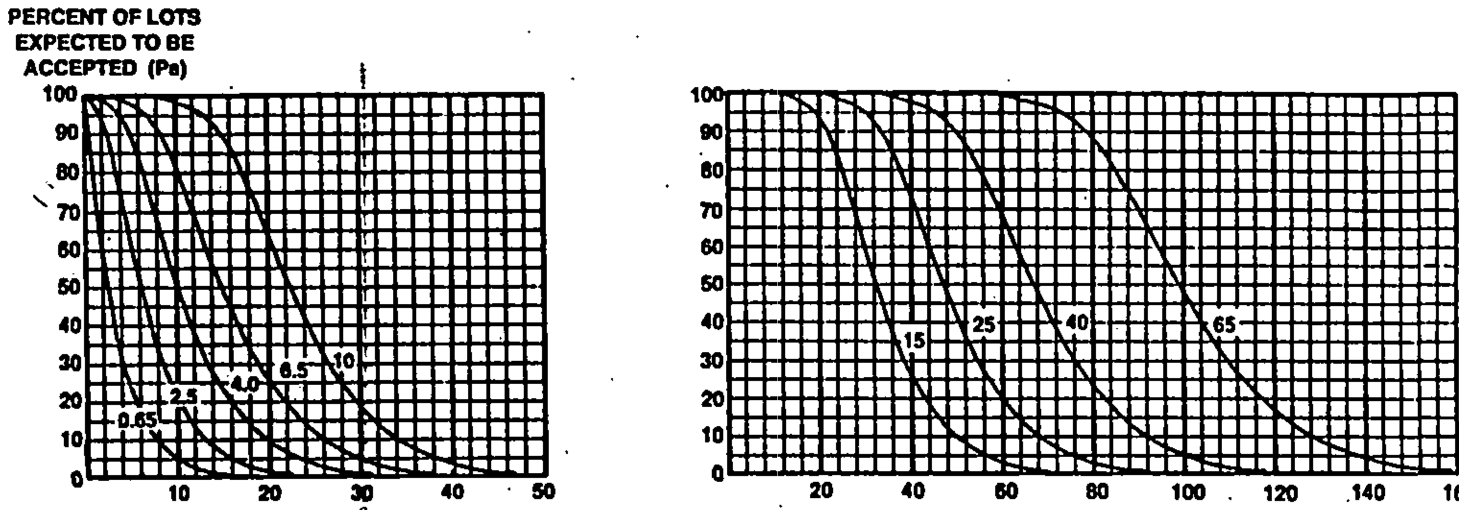
TABLE C-E- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS														
	1.0	4.0	6.5	10	1.0	4.0	6.5	10	15	25	40	65	100	150	250
	p(percent defective)				p(defects per hundred units)										
99.0	0.077	1.18	3.56	6.92	0.077	1.14	3.34	6.32	13.7	22.3	36.7	57.5	96.6	150	237
95.0	0.385	2.73	6.24	10.9	0.386	2.66	5.96	10.2	19.2	29.7	46.6	70.3	113	171	265
90.0	0.783	3.88	7.85	13.1	0.756	3.79	7.58	12.5	22.1	33.6	51.8	77.0	121	182	278
75.0	1.81	6.15	10.9	17.2	1.82	6.13	10.8	16.8	27.3	40.4	60.6	88.3	135	199	301
50.0	3.92	9.83	15.5	22.9	4.00	9.80	15.6	23.4	34.8	49.7	72.6	103	153	221	329
25.0	7.44	14.5	22.0	30.3	7.73	15.2	23.4	32.6	45.0	62.4	88.0	122	174	248	362
10.0	12.0	20.2	29.3	38.2	12.8	21.9	32.8	43.5	57.3	78.7	105	141	197	275	394
5.0	15.4	24.2	34.3	43.3	16.7	26.8	39.6	51.2	66.1	88.6	116	154	213	293	415
1.0	23.1	33.0	44.2	53.0	26.2	38.6	54.8	67.9	85.2	108	140	181	244	329	457

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-F FOR SAMPLE SIZE CODE LETTER: F

CHART C-F - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's ≤ 10; in defects per hundred units for AQL's > 10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

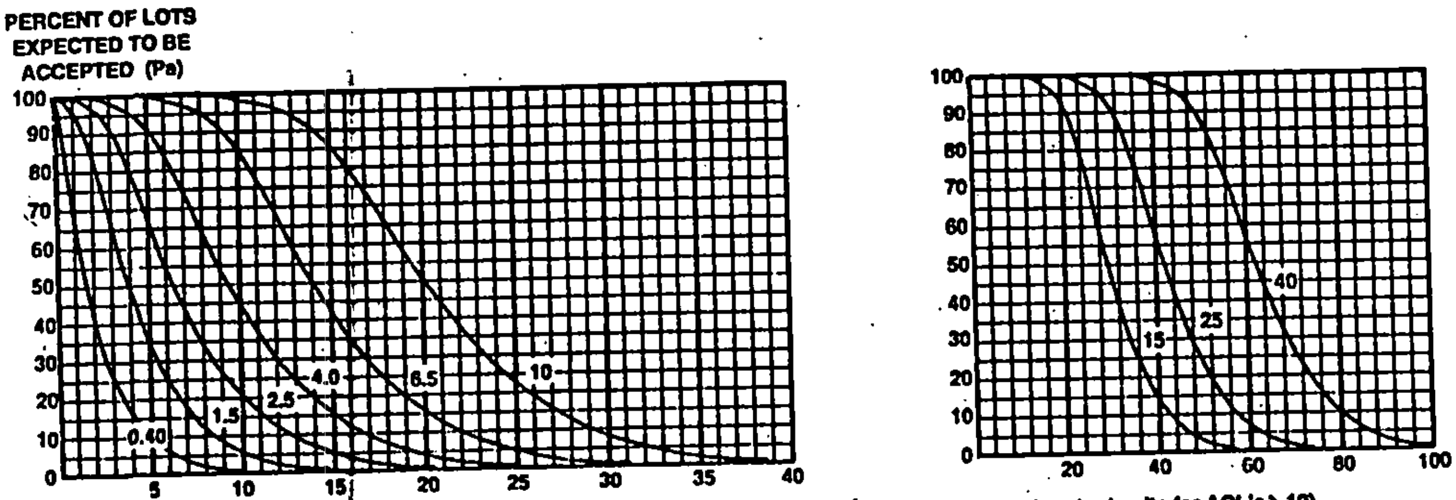
TABLE C-F-TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS													
	.65	2.5	4.0	6.5	10	.65	2.5	4.0	6.5	10	15	25	40	65
	p(percent defective)					p(defects per hundred units)								
99.0	0.050	0.758	2.26	4.35	9.70	0.050	0.742	2.17	4.11	8.88	14.6	23.8	37.4	62.8
95.0	0.250	1.76	3.99	6.90	13.3	0.250	1.72	3.87	6.81	12.6	19.3	30.3	45.7	73.5
90.0	0.488	2.47	5.04	8.38	15.1	0.488	2.45	4.93	8.12	14.3	21.8	33.6	50.0	78.9
75.0	1.16	3.93	7.05	11.1	18.2	1.17	3.92	7.00	10.9	17.7	26.2	39.4	57.4	87.7
50.0	2.61	6.16	10.1	15.0	22.4	2.54	6.23	10.3	15.2	22.5	32.3	47.2	67.0	99.2
25.0	4.77	9.35	14.6	20.2	27.9	4.89	9.63	15.2	21.2	29.3	40.5	57.2	79.1	113
10.0	7.76	13.2	19.8	26.0	34.1	8.08	13.9	21.3	28.3	37.3	49.8	68.1	91.8	128
5.0	10.0	16.0	23.4	29.8	38.2	10.6	17.0	25.7	33.3	42.9	56.3	75.5	100	138
1.0	15.4	22.3	31.0	37.8	46.5	16.7	24.7	35.8	44.1	55.4	70.0	90.9	118	158

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-G FOR SAMPLE SIZE CODE LETTER: G

CHART C-G - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

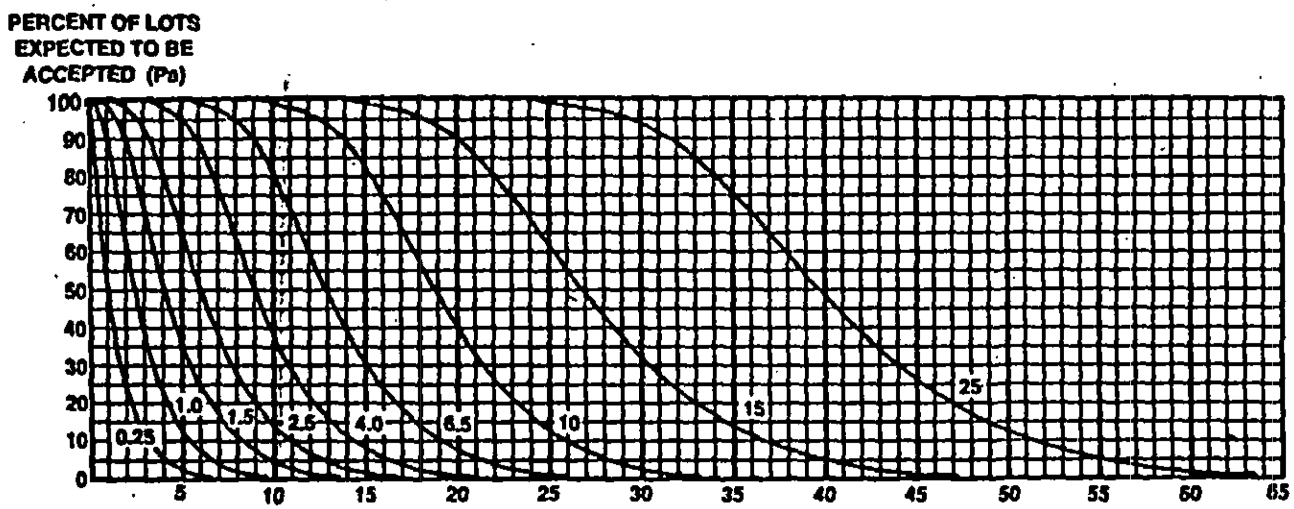
TABLE C-G-TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS														
	0.40	1.5	2.5	4.0	6.5	10	0.40	1.5	2.5	4.0	6.5	10	15	25	40
	p(percent defective)						p(defects per hundred units)								
99.0	0.031	0.470	1.39	2.68	5.85	9.71	0.031	0.463	1.38	2.57	5.55	9.06	14.9	23.3	39.3
95.0	0.158	1.09	2.47	4.24	8.06	12.7	0.158	1.08	2.42	4.13	7.78	12.1	18.9	28.6	46.0
90.0	0.306	1.65	3.12	5.17	9.23	14.2	0.308	1.54	3.08	5.07	8.97	13.6	21.0	31.3	49.3
75.0	0.733	2.48	4.39	6.89	11.1	16.7	0.736	2.47	4.37	6.84	11.1	18.4	24.6	35.9	54.8
50.0	1.60	3.92	6.37	9.41	14.0	20.1	1.61	3.95	6.42	9.50	14.1	20.2	29.5	41.9	62.0
25.0	3.06	6.00	9.26	12.9	17.8	24.5	3.11	6.11	9.50	13.3	18.3	25.3	35.7	49.4	70.9
10.0	5.00	8.52	12.7	16.8	22.0	29.2	5.13	8.79	13.3	17.7	23.3	31.2	42.6	57.4	80.2
5.0	6.49	10.4	15.2	19.4	25.0	32.3	6.71	10.8	16.1	20.8	26.8	35.2	47.2	62.6	86.4
1.0	10.0	14.6	20.4	25.0	31.0	38.5	10.6	15.6	22.3	27.6	34.6	43.8	56.8	73.5	99.0

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-H FOR SAMPLE SIZE CODE LETTER: H

CHART C-H - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's < 10; in defects per hundred units for AQL's > 10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

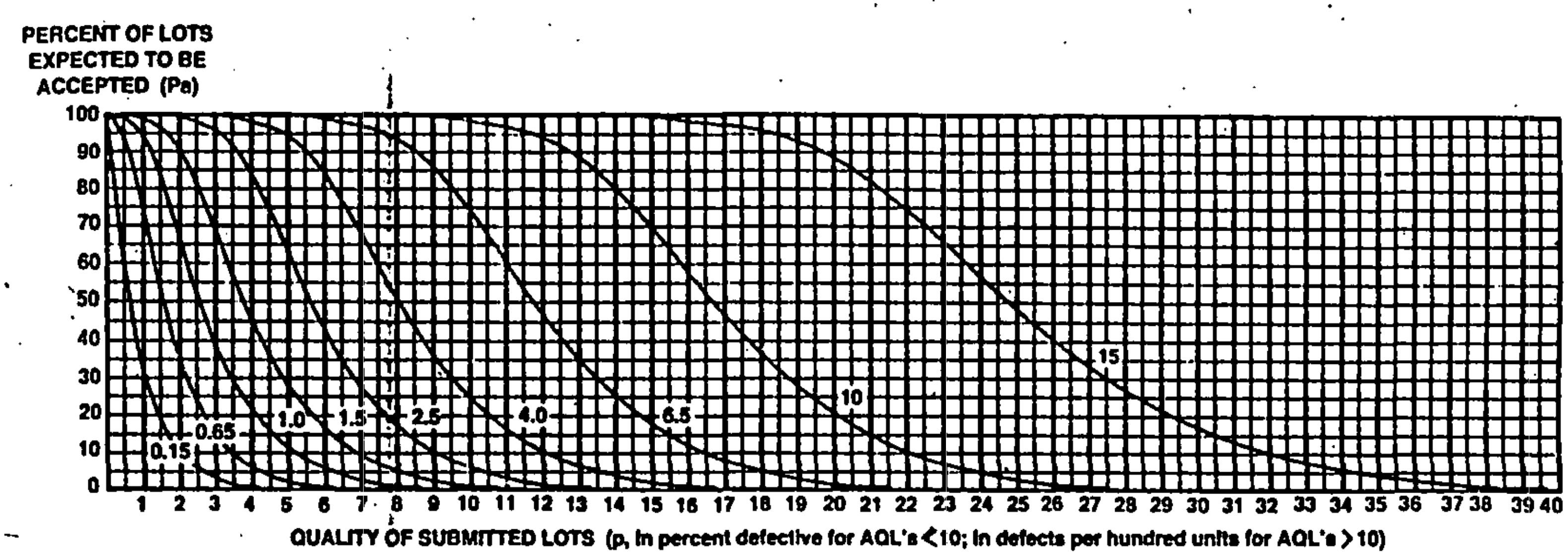
TABLE C-H- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS															
	0.25	1.0	1.5	2.5	4.0	6.5	10	0.25	1.0	1.5	2.5	4.0	6.5	10	15	25
	p(percent defective)							p(defects per hundred units)								
99.0	0.020	0.299	0.881	1.68	3.67	6.05	10.1	0.020	0.297	0.868	1.64	3.55	5.80	9.53	14.9	25.1
95.0	0.100	0.694	1.57	2.69	5.10	7.96	12.6	0.100	0.690	1.55	2.65	4.98	7.72	12.1	18.3	29.4
90.0	0.195	0.983	1.99	3.29	5.84	8.94	13.9	0.195	0.979	1.97	3.25	5.74	8.73	13.5	20.0	31.6
75.0	0.485	1.57	2.81	4.40	7.15	10.6	16.0	0.486	1.57	2.80	4.38	7.09	10.5	15.8	22.9	35.1
50.0	1.01	2.48	4.09	6.04	8.98	12.9	18.8	1.02	2.49	4.11	6.08	9.01	12.9	18.9	26.8	39.7
25.0	1.94	3.81	5.98	8.33	11.5	15.9	22.3	1.96	3.85	6.08	8.49	11.7	16.2	22.9	31.6	45.3
10.0	3.18	5.43	8.28	10.9	14.4	19.1	25.9	3.23	5.54	8.52	11.3	14.9	19.9	27.2	36.7	51.3
5.0	4.14	6.64	9.91	12.7	16.4	21.3	28.3	4.23	6.82	10.3	13.3	17.2	22.5	30.2	40.1	55.3
1.0	6.47	9.50	13.5	16.6	20.7	25.8	33.1	6.69	9.89	14.3	17.7	22.2	28.0	36.4	47.0	63.4

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-J FOR SAMPLE SIZE CODE LETTER: J

CHART C-J - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

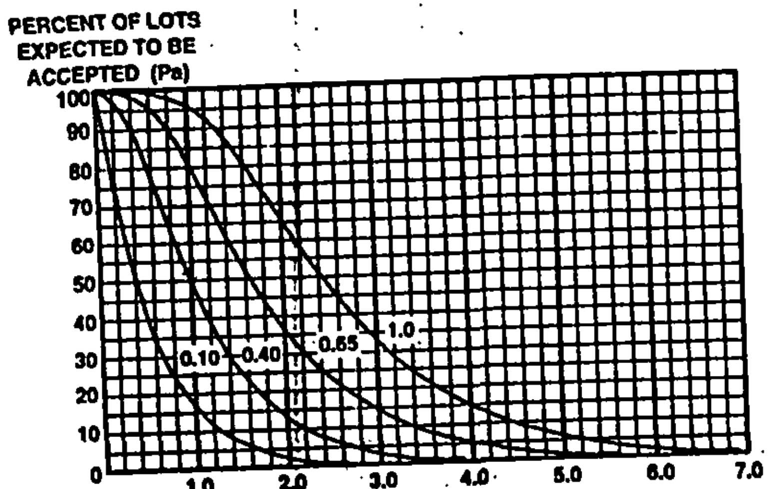
TABLE C-J-TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

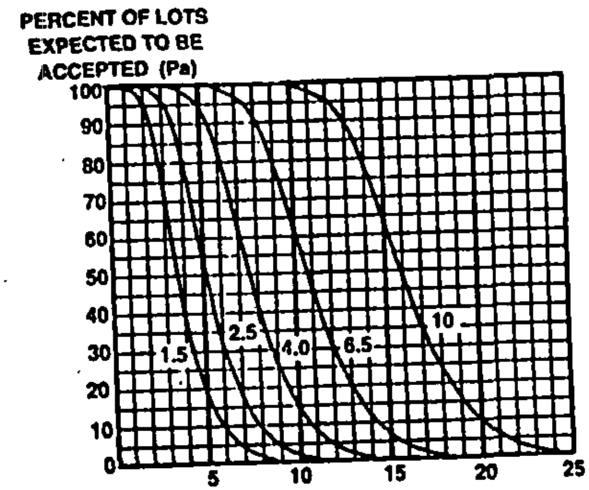
Pa	ACCEPTABLE QUALITY LEVELS																
	0.15	0.65	1.0	1.5	2.5	4.0	6.5	10	0.15	0.65	1.0	1.5	2.5	4.0	6.5	10	15
	p(percent defective)								p(defects per hundred units)								
99.0	0.013	0.186	0.548	1.04	2.27	3.72	6.16	9.75	0.013	0.185	0.542	1.03	2.22	3.62	5.96	9.34	15.7
95.0	0.063	0.434	0.975	1.67	3.16	4.92	7.76	11.8	0.063	0.432	0.968	1.65	3.11	4.83	7.57	11.4	18.4
90.0	0.122	0.616	1.24	2.04	3.63	5.54	6.57	12.8	0.122	0.615	1.23	2.03	3.59	5.46	6.41	12.5	19.7
75.0	0.294	0.990	1.75	2.74	4.46	6.61	9.94	14.5	0.294	0.990	1.75	2.74	4.43	6.56	9.65	14.3	21.9
50.0	0.642	1.57	2.66	3.79	5.62	8.06	11.8	16.7	0.644	1.58	2.57	3.80	5.63	8.08	11.8	16.6	24.8
25.0	1.24	2.43	3.76	5.24	7.23	9.99	14.1	19.4	1.24	2.44	3.60	5.30	7.31	10.1	14.3	19.8	28.3
10.0	2.03	3.47	5.23	6.92	9.11	12.1	16.5	22.1	2.05	3.52	5.32	7.07	9.32	12.5	17.0	23.0	32.1
5.0	2.65	4.25	6.28	8.09	10.4	13.6	18.1	23.9	2.68	4.32	6.43	8.31	10.7	14.1	18.9	25.1	34.6
1.0	4.14	6.06	8.60	10.6	13.3	16.6	21.4	27.4	4.23	6.24	8.91	11.0	13.8	17.5	22.7	29.4	39.6

Note: Binomial distribution used for percent defective computation; Poisson for defects per hundred units.

TABLE AND CHART C-K FOR SAMPLE SIZE CODE LETTER: K

CHART C-K - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES





QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's ≤ 10; in defects per hundred units for AQL's > 10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

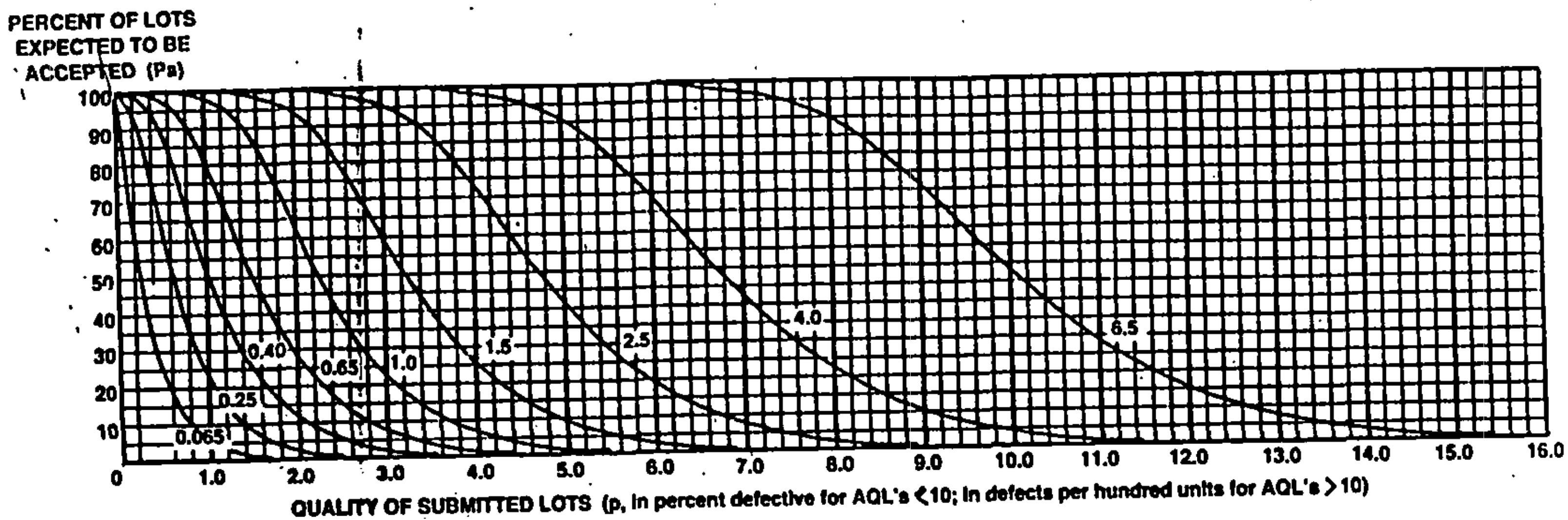
TABLE C-K- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS								
	0.10	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10
	p(percent defective or defects per hundred units)								
99.0	0.0080	0.119	0.349	0.663	1.44	2.38	3.89	6.14	10.4
95.0	0.0400	0.278	0.623	1.07	2.01	3.13	4.92	7.45	12.1
90.0	0.0780	0.392	0.791	1.30	2.31	3.53	5.45	8.13	12.9
75.0	0.188	0.627	1.12	1.75	2.85	4.22	6.34	9.25	14.2
50.0	0.405	0.995	1.64	2.43	3.60	5.17	7.53	10.7	15.8
25.0	0.779	1.53	2.42	3.37	4.65	6.43	9.05	12.5	17.9
10.0	1.28	2.20	3.37	4.46	5.88	7.84	10.7	14.4	20.0
5.0	1.68	2.70	4.05	5.23	6.75	8.81	11.8	15.6	21.4
1.0	2.64	3.89	5.57	6.68	8.62	10.8	14.0	18.0	24.1

Note: Binomial distribution used in all computations in above table.

TABLE AND CHART C-L FOR SAMPLE SIZE CODE LETTER: L

CHART C-L - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

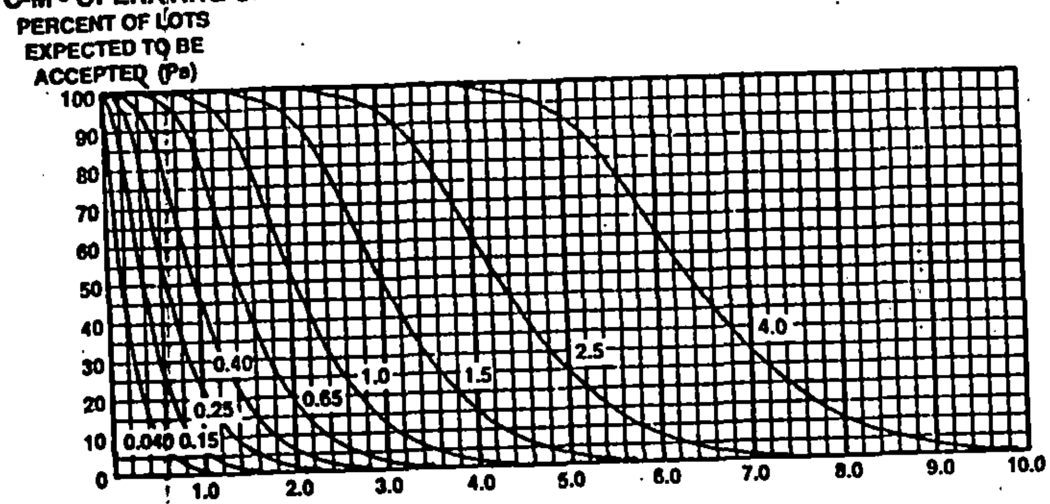
TABLE C-L - TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS								
	0.065	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5
	p(percent defective or defects per hundred units)								
99.0	0.0050	0.074	0.218	0.413	0.895	1.46	2.41	3.80	6.42
95.0	0.0250	0.173	0.388	0.664	1.25	1.95	3.06	4.62	7.47
90.0	0.0489	0.248	0.494	0.814	1.44	2.20	3.39	5.05	7.98
75.0	0.117	0.395	0.700	1.10	1.78	2.63	3.95	5.76	8.83
50.0	0.256	0.628	1.03	1.52	2.25	3.23	4.71	6.69	9.91
25.0	0.493	0.970	1.51	2.11	2.91	4.03	5.68	7.85	11.2
10.0	0.818	1.39	2.11	2.80	3.69	4.93	6.73	9.05	12.6
5.0	1.06	1.71	2.55	3.29	4.25	5.55	7.43	9.84	13.5
1.0	1.67	2.46	3.51	4.34	5.44	6.86	8.88	11.4	15.4

Note: Binomial distribution used in all computations in above table.

TABLE AND CHART C-M FOR SAMPLE SIZE CODE LETTER: M

CHART C-M - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



QUALITY OF SUBMITTED LOTS (p, In percent defective for AQL's ≤10; In defects per hundred units for AQL's >10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

TABLE C-M- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

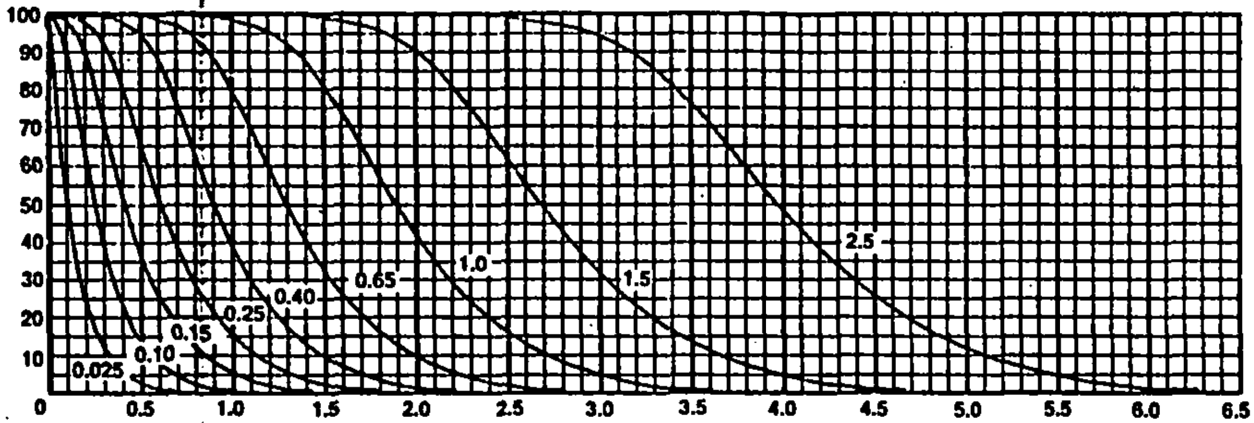
Pa	ACCEPTABLE QUALITY LEVELS								
	0.040	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0
	p(percent defective or defects per hundred units)								
99.0	0.0032	0.047	0.138	0.262	0.567	0.926	1.53	2.40	4.04
95.0	0.0159	0.110	0.246	0.421	0.793	1.23	1.93	2.92	4.71
90.0	0.0310	0.156	0.313	0.516	0.913	1.39	2.15	3.19	5.05
75.0	0.0742	0.250	0.444	0.695	1.13	1.67	2.51	3.85	5.59
50.0	0.162	0.397	0.652	0.964	1.43	2.05	2.99	4.25	6.29
25.0	0.312	0.613	0.963	1.34	1.85	2.56	3.62	5.00	7.16
10.0	0.514	0.882	1.35	1.79	2.35	3.14	4.29	5.78	8.07
5.0	0.673	1.08	1.62	2.10	2.71	3.54	4.74	6.29	8.66
1.0	1.06	1.56	2.24	2.77	3.48	4.39	5.69	7.34	9.86

Note: Binomial distribution used in all computations in above table.

TABLE AND CHART C-N FOR SAMPLE SIZE CODE LETTER: N

CHART C-N - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

PERCENT OF LOTS EXPECTED TO BE ACCEPTED (Pa)



QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's < 10; in defects per hundred units for AQL's > 10)

Note: Figures on curves are Acceptable Quality Levels AQL's) for tightened-normal inspection.

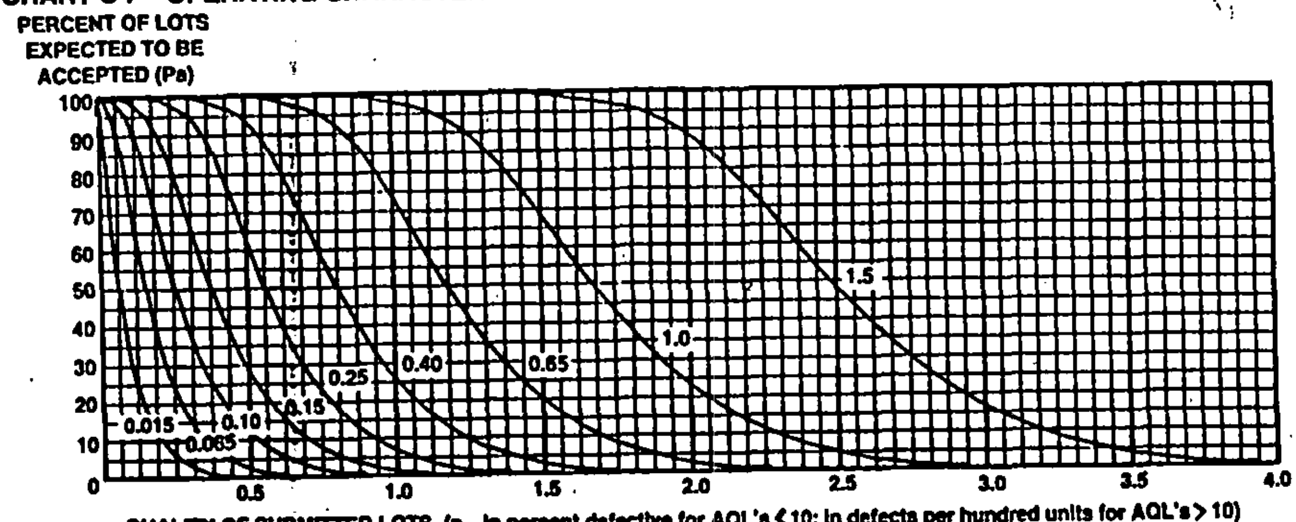
TABLE C-N- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS								
	0.025	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5
	p(percent defective or defects per hundred units)								
99.0	0.0020	0.0297	0.0669	0.165	0.356	0.582	0.958	1.50	2.53
95.0	0.0100	0.0690	0.155	0.265	0.499	0.775	1.22	1.84	2.96
90.0	0.0195	0.0979	0.197	0.325	0.575	0.875	1.35	2.01	3.17
75.0	0.0466	0.157	0.280	0.438	0.709	1.05	1.58	2.30	3.52
50.0	0.101	0.249	0.411	0.607	0.901	1.29	1.89	2.68	3.96
25.0	0.195	0.385	0.607	0.847	1.17	1.62	2.28	3.15	4.52
10.0	0.323	0.553	0.850	1.13	1.49	1.99	2.71	3.65	5.10
5.0	0.422	0.680	1.03	1.32	1.71	2.24	3.00	3.98	5.48
1.0	0.666	0.985	1.42	1.75	2.20	2.78	3.60	4.65	6.26

Note: Binomial distribution used in all computations in above table.

TABLE AND CHART C-P FOR SAMPLE SIZE CODE LETTER: P

CHART C-P - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

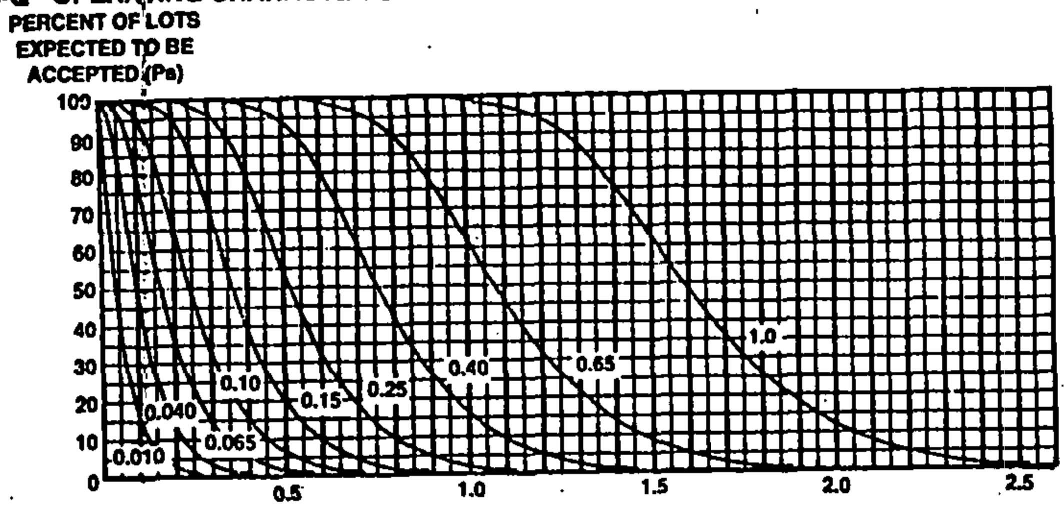
TABLE C-P- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS								
	0.015	0.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5
	p(percent defective or defects per hundred units)								
99.0	0.0013	0.0188	0.0543	0.103	0.223	0.363	0.598	0.938	1.58
95.0	0.0063	0.0432	0.0969	0.166	0.312	0.484	0.759	1.15	1.85
90.0	0.0122	0.0615	0.123	0.203	0.359	0.547	0.843	1.25	1.98
75.0	0.0294	0.0990	0.175	0.274	0.443	0.656	0.986	1.44	2.20
50.0	0.0644	0.158	0.257	0.380	0.563	0.808	1.18	1.68	2.48
25.0	0.124	0.244	0.360	0.530	0.731	1.01	1.43	1.97	2.83
10.0	0.205	0.351	0.532	0.706	0.930	1.24	1.70	2.29	3.20
5.0	0.268	0.431	0.642	0.829	1.07	1.40	1.88	2.49	3.44
1.0	0.422	0.623	0.888	1.10	1.38	1.74	2.26	2.92	3.93

Note: Binomial distribution used in all computations in above table.

TABLE AND CHART C-Q FOR SAMPLE SIZE CODE LETTER: Q

CHART C-Q - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

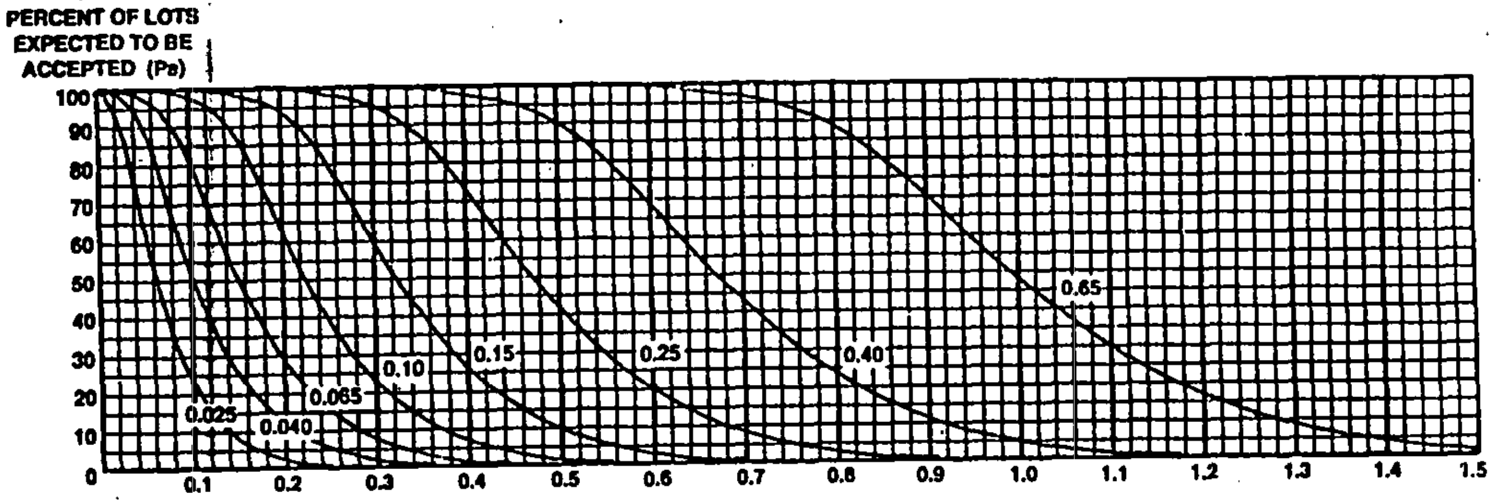
TABLE C-Q TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS								
	0.010	0.040	0.065	0.10	0.15	0.25	0.40	0.65	1.0
	p(percent defective or defects per hundred units)								
99.0	0.00080	0.0119	0.0347	0.0657	0.142	0.232	0.382	0.599	1.01
95.0	0.00400	0.0278	0.0620	0.108	0.199	0.309	0.485	0.732	1.18
90.0	0.00780	0.0391	0.0789	0.130	0.230	0.350	0.539	0.802	1.26
75.0	0.0186	0.0627	0.112	0.175	0.284	0.420	0.631	0.919	1.40
50.0	0.0406	0.0997	0.164	0.243	0.360	0.517	0.754	1.07	1.59
25.0	0.0782	0.154	0.243	0.339	0.468	0.648	0.914	1.26	1.81
10.0	0.129	0.222	0.340	0.452	0.595	0.796	1.09	1.47	2.05
5.0	0.169	0.272	0.411	0.531	0.686	0.898	1.20	1.60	2.20
1.0	0.267	0.395	0.569	0.705	0.884	1.12	1.45	1.87	2.52

Note: Binomial distribution used in all computations in above table.

TABLE AND CHART C-R FOR SAMPLE SIZE CODE LETTER: R

CHART C-R - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



QUALITY OF SUBMITTED LOTS (p, In percent defective for AQL's <10; In defects per hundred units for AQL's >10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

TABLE C-R- TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS								
	0.025	0.040	0.065	0.10	0.15	0.25	0.40	0.65	
	p(percent defective or defects per hundred units)								
99.0	0.0074	0.0217	0.0411	0.0889	0.145	0.239	0.374	0.629	
95.0	0.0173	0.0388	0.0682	0.125	0.193	0.303	0.457	0.738	
90.0	0.0245	0.0493	0.0812	0.144	0.218	0.337	0.501	0.790	
75.0	0.0395	0.0700	0.109	0.177	0.262	0.394	0.574	0.878	
50.0	0.0629	0.103	0.152	0.225	0.323	0.472	0.670	0.991	
25.0	0.0972	0.152	0.212	0.292	0.405	0.571	0.790	1.13	
10.0	0.140	0.213	0.283	0.372	0.498	0.680	0.917	1.28	
5.0	0.172	0.257	0.332	0.429	0.562	0.754	1.00	1.38	
1.0	0.249	0.356	0.441	0.553	0.699	0.907	1.17	1.58	

Note: Binomial distribution used in all computations in above table.

APPENDIX D: OTHER NONCONFORMANCE TERMINOLOGY

D.10.1 Introduction. The American Society for Quality Control (ASQC) has developed terminology to describe nonconformance of product that is different from the nonconformance terminology described in Section 3. ASQC sponsored the development because many quality control/ quality assurance professionals felt that the changed terminology would be more usable for them and more understandable for the layman. The terminology of Section 3, however, will continue to be used in DOD for the present, at least, since making the change would be costly and time consuming, requiring the revisionsof many item specifications, contracts, regulations, standards, etc. Nevertheless, since readers may encounter the ASQC terminology, some of it is presented below, not only to acquaint readers with its content, but also to alert them to the fact that certain words are used in both sets of terminology, but with different meanings. The four terms given below are related to acceptance sampling and are found in ANSI/ASQC Std. A2-1978. Further terms relating to quality control are found in ANSI/ASQC Std. A1-1978. Notice that the definitions for nonconformity and nonconforming unit below are the definitions of defect and defective in the present DOD terminology and that defect and defective are given new definitions.

D.10.2 Nonconformity. A departure of a quality characteristic from its intended level or state that occurs with a severity sufficient to cause an associated product or service not to meet a specification requirement.

COMMENT: In some situations specification requirements coincide with customer usage requirements (see definition of defect). In other situations they may not coincide, being either more or less stringent, or the exact relationship between the two may not be fully known or understood. When a quality characteristic of a product or service is "evaluated" in terms of conformance to specifications requirements, the use of the term nonconformity is appropriate. Contractual obligations, stated or implicit, may be involved in certain instances, but in others the specification requirements may be purely internal and set deliberately tighter than the customer requirement.

D.10.3 Nonconforming Unit. A unit of product or service containing at least one nonconformity.

COMMENT: See comment under 3.4.1, Nonconformity.

NOTE: More stringent sampling (e.g., smaller AQL values) is usually used for those types of nonconformities which are considered more important.

D.10.4 Defect. A departure of a quality characteristic from its intended level or state that occurs with a severity sufficient to cause an associated product or service not to satisfy intended normal, or reasonable foreseeable, usage requirements.

COMMENT: The word defect is appropriate for use when a quality characteristic of a product or service is evaluated in terms of usage (as contrasted to conformance to specifications).

D.10.5 Defective (Defective Unit). A unit of product or service containing at least one defect, or having several imperfections that in combination cause the unit to fail to satisfy intended normal or reasonably foreseeable usage requirements.

COMMENT: The word defective is appropriate for use when a unit of product or service is evaluated in terms of customer usage (as contrasted to conformance to specifications).

D.10.6 Seriousness of Defects. ANSI/ASQC Std. A1-1978 states that defects will generally be classified by degree of seriousness and suggests the following possible classifications and classification modifiers:

Class	Modifier	Description
1	Very Serious	Leads directly to severe injury or catastrophic economic loss.
2	Serious	Leads directly to significant injury or significant economic loss.
3	Major	Related to major problems with respect to intended normal or reasonably foreseeable use.
4	Minor	Related to minor problems with respect to intended normal or reasonably foreseeable use.

INDEX PAGE

INDEX PAGE

Custodian:
Navy - SH
Air Force - 23
DLA - DH

Review activities:
Army - AT, CR, GL, AV, AL, EA
Navy - OS, AS, EC, YD
Air Force - 99

Preparing activity:
Army - AR

Project Number: QCIC-0004-01

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