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Quality Assurance Software for the Personal Computer

Demonstration Project 89

Technology Applications

Innovation Through Partnerships

NOTICE

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16. Abstract

Demonstration Project 89 on Quality Management was created to provide guidance on the use of practical and effective quality assurance procedures for highway construction projects. The intent is to assure that the level of quality designed into the plans and specifications is actually achieved in the finished product. One part of this effort is the distribution of a software package consisting of several interactive programs developed for use on the personal computer. These extremely user-friendly programs enable the user to analyze both pass/fail and pay adjustment acceptance procedures, construct operating characteristic curves, plot control charts, experiment with computer simulation, perform statistical comparisons of data sets, demonstrate the unreliability of decisions based on a single test result, and explore the effectiveness of stratified random sampling. This comprehensive software package provides highway engineers with the necessary tools to learn why some statistical procedures are inherently superior to others and how to incorporate this knowledge into fair and effective construction specifications.

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PREFACE

One of the nation's most valuable assets is the network of roads and bridges linking the suppliers of goods and services with their customers. National economic well-being is dependent upon the condition of the highway system and that, in turn, is inexorably linked to the quality of design and the quality of construction. To control the quality of construction, highway agencies have developed elaborate quality assurance programs based on statistical sampling and acceptance procedures to ensure that the work is in accordance with the plans and specifications.

But not all quality assurance programs are effective nor are all acceptance procedures fair to both the contractor and the highway agency. Statistical quality assurance is one of the most useful tools a highway agency has at its disposal, but only if it is used correctly. It is the purpose of Demonstration Project 89 to provide the knowledge and understanding to encourage the correct use of the most effective methods.

One part of this effort is the distribution of a software package consisting of several interactive programs developed for use on the personal computer. These extremely user friendly programs place an enormous amount of analytical power in the hands of highway engineers and specification writers, making it easy to demonstrate the superiority of some procedures and the ineffectiveness of others. It is hoped that the availability of this software will promote a better appreciation of both the capabilities and the limitations of statistical methods and that it will help to motivate the consistent use of sound engineering and statistical principles in highway construction specifications.

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CHAPTER 1

INTRODUCTION

1.1 NATIONAL QUALITY INITIATIVE

Many statistical quality assurance (SQA) procedures in use today were developed long before statistical science was a requirement in the typical engineering curriculum. Consequently, many existing SQA specifications have never been thoroughly analyzed to confirm that they will perform as intended. In response to a growing concern that current quality assurance practices were not providing the desired degree of highway quality, the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO, formerly AASHO), and several industry associations joined forces in 1992 to form a unique partnership termed the National Quality Initiative (NQI). Its stated goal was to promote the improvement of highway product quality as one of the keys to national economic competitiveness.

The long-range plan of the NQI defines a broad series of objectives and activities designed to raise the level of consciousness on quality issues. These activities are concentrated heavily on education, training, and information exchange in the belief that knowledge and understanding are ultimately the best motivators. This effort is consistent with, and will be aided by, the current strong interest in Total Quality Management (TQM) with its emphasis on continuous process improvement, data-driven decision making, and the notion that quality is everyone's responsibility.

1.2 DEMONSTRATION PROJECT 89

FHWA Demonstration Project 89 on Quality Management is the parent program that led to the creation of the NQI. It is the purpose of this broader program to move beyond often vague motivational rhetoric and provide guidance on practical and effective procedures that can readily be implemented to ensure that the level of quality designed into the plans and specifications is actually achieved in the constructed product.

Two training programs are currently being offered by FHWA. A 2-day seminar (Demonstration Project 89), directed primarily at middle and upper level management, combines TQM thinking with an overview of the state of the art of SQA. This ordinarily is the forerunner of the second program, a 5-day training course (NHI Course 13442) that presents basic statistical principles in greater detail and illustrates how they can be applied to develop fair and effective construction specifications.

One part of this effort is the distribution of a software package consisting of several interactive programs developed for use on the personal computer. These extremely user friendly programs place an enormous amount of analytical power in the hands of highway engineers and specifications writers, making it possible to learn why some statistical procedures are inherently superior to others and how to incorporate this knowledge into fair and effective construction specifications.

1.3 STATISTICAL QUALITY ASSURANCE IN HIGHWAY CONSTRUCTION

The AASHO Road Test provided the data in the early 1960s that illustrated in a dramatic way how variable most construction characteristics are. Concrete strength, asphalt content, pavement thickness, and many other construction measures were found to vary widely about their target values, usually in the form of the bell-shaped normal distribution. The tails of these distributions often extended well into regions that were thought to represent unacceptable performance. What was initially perceived as disturbing news, however, turned out to be beneficial as highway engineers first learned to understand the statistical principles underlying this behavior and then began to develop construction specifications based on these concepts.

As more was learned about construction variability, it became apparent that the desired end result could be expressed in statistical terms. This freed highway agencies from the burden of having to describe the construction process in detail as was the practice with the method-type specifications then in use. The new approach not only gave contractors more latitude to use their ingenuity to obtain the desired end result in more efficient ways, but also placed the responsibility for producing quality workmanship directly on those performing the work. This shift is consistent with current management philosophy and led to the logical division of responsibility whereby *quality control* refers to those activities undertaken by the contractor to meet specification requirements and the *acceptance program* refers to the acceptance testing and other activities performed by the highway agency to verify that specification requirements have been met.

Although the construction measures observed at the AASHO Road Test did have considerable variability, it was equally clear that many of the pavements and structures built under these conditions performed very satisfactorily. What had not been realized previously is that the existence of a relatively small percentage of tests falling outside specification limits was normal and not necessarily detrimental to performance. This led to the definition of the acceptable quality level (AQL), stated either in terms of the percentage of a lot falling outside specification limits (percent defective or PD) or the corresponding percentage of the lot falling within specification limits (percent within limits or PWL). Historical data was used to determine what levels of PD or PWL corresponded to satisfactory performance and, therefore, would be suitable as the AQL upon which a construction specification could be based. Typical values used in the highway field are percent defective levels of PD = 5 and PD = 10 or the corresponding percent within limits values of PWL = 95 and PWL = 90.

The methodology for developing acceptance procedures based on this concept had already been used successfully in both private industry and the military. But whereas these applications classified as rejectable any lots found to be of lower quality than the AQL, such a sharp distinction was not considered appropriate for most highway construction items. Highway engineers felt more comfortable defining a high level of quality that was clearly acceptable (AQL) and another, substantially lower level of quality that was clearly rejectable (rejectable quality level or RQL). In between the AQL and the RQL, the work was not so defective that removal and replacement was necessary but neither was it good enough to warrant acceptance at full payment. This led to the concept of adjusted payment that provided for prearranged levels of pay reduction for items of work found to be marginally defective.

It was eventually realized that, if it made sense to withhold payment for substandard work, it might also make sense to offer some degree of monetary incentive for work that exceeds the AQL. Just as the justification for reducing payment for marginally defective work is based on the anticipated increase in future maintenance and repair costs, it was recognized that superior quality usually benefits the highway agency by reducing these same costs and that it was justifiable to pass some of these savings back to the conscientious contractor in the form of modest incentive payments in addition to the contract bid price.

The incentive pay concept was initially supported by the FHWA as an experimental feature. After several years of satisfactory experience, it was approved for general use and is now a standard feature in many highway construction specifications. Not only did this tend to soften the punitive perception the construction industry had of SQA specifications, it provided an increased incentive to produce high-quality work believed to be in the best interest of all concerned. The inclusion of an incentive pay provision also makes it possible to ensure that truly AQL work will receive an average pay factor of 100 percent payment, an important feature that will be illustrated in one of the examples in chapter 3. With the advent of the incentive pay provision, the pay reduction side of the equation began to play less of a role in actual practice but remains as an important safeguard against the occasional lot that, for one reason or another, fails to achieve the desired level of quality.

When an acceptance procedure is designed or analyzed, the AQL and the RQL are the primary points of interest in evaluating its performance. When the work is truly at the AQL, it should nearly always be accepted or receive an average pay factor of 100 percent, depending upon whether a pass/fail or pay adjustment procedure is being used. When the work is truly at the RQL, it should nearly always be rejected or receive a pay reduction sufficiently large to cover the cost of the anticipated future repairs resulting from deficient quality. Program OCPLOT, one of the programs described in this manual, provides a convenient way to perform this analysis.

The development of the first SQA specifications was largely a trial-and-error process and several tries were often needed before a workable specification was obtained. Modern SQA specifications are the result of a continuing evolutionary process and contain many improvements and refinements not present in the earlier versions. As highway engineers have developed a better understanding of the operation of SQA procedures, this newly acquired knowledge has been reflected in more effective acceptance procedures with properly balanced risks and fair and equitable adjusted payment provisions. As the level of sophistication has increased, the computer has emerged as a valuable aid in performing much of the developmental and analytical work. The PC programs described in this manual will help to illustrate why SQA specification writing is no longer an empirical art but must now be regarded as a thoroughly scientific process.

CHAPTER 2

GENERAL PROGRAM INFORMATION

2.1 SYSTEM REQUIREMENTS

A DOS operating system is required. For best results, the programs should be run on a machine using an Intel compatible 80386 (or higher) processor. A monochrome monitor is sufficient but considerably greater clarity is achieved on a color monitor.

The complete set of operational programs and support modules requires somewhat less than one and one-half megabytes of disk space. The largest single program, OCPLOT, consists of a total of seven modules and requires slightly more than half a megabyte.

2.2 INSTALLATION AND OPERATION

The programs may be run from a disk drive or loaded onto the hard drive. If run from a disk drive, control must first be transferred to the disk drive by entering the appropriate drive designation before entering the program name. This is necessary because all of the programs require support modules and search for them on the drive from which the programs are being run.

If the programs are to be loaded onto the hard drive, it is advisable to put them on a subdirectory created just for that purpose. This can be accomplished by placing the Demonstration Project 89 diskette in drive A: and entering the following DOS commands:

COMMAND	ACTION
md dp89	Creates subdirectory DP89 (or choose other suitable name) on hard drive
cd dp89	Switches control to subdirectory DP89
copy a:*.*	Copies all files on diskette in drive A:

If only certain programs are to be selectively loaded onto the hard drive, all necessary support modules must be included, a list of which is found with the descriptions of the programs in this chapter. They are also listed on the opening screen of each program.

The programs are designed to be essentially self-explanatory so that very little instruction is required in order to run them. All programs are started by entering the name (OCPLOT, CONCHART, DATATEST, etc.). The first two displays identify the programs as part of Demonstration Project 89 on Quality Management and state the function of the program. The next screen provides basic operational information. Execution is then halted until the user strikes any key to continue.

The demonstration programs OCDEMO and CCDEMO require no further input and will run continuously until stopped by pressing the <END> key. The other programs provide a series of menus and prompts to guide the user, including a variety of internal checks that may cause either CAUTION or WARNING messages to appear on the screen to provide additional guidance.

2.3 PROGRAMMING LANGUAGE AND STYLE

The programming is done in Microsoft QuickBASIC. The programs consist of the primary [NAME].EXE modules and several support modules that perform various functions. Within the modules, the programming is highly structured and makes use of many subroutines. The programming includes variables lists, outlines of program labels, and many remarks that may make it possible for users to make minor revisions. The source coding is not provided on the diskette but may be obtained from either the author or the Demonstration Project 89 Project Manager.

2.4 SPECIAL FEATURES

The programming includes various checks in an attempt to anticipate a variety of potential problems. Where it is possible to know in advance that certain input values are improper, appropriate parts of the keyboard are inactivated. In other cases, the programs perform many internal checks to guard against the entry of inappropriate values. If the entered value has the potential of producing an undesirable result, a CAUTION message is displayed (color coded yellow) that allows the user the option of either continuing or entering a different value. If the entered value will result in a condition that is clearly inappropriate, a WARNING message appears (color coded red) that requires the user to enter a different value.

For example, if certain entry values can only be positive, the key with the minus sign is inactivated. When the input requires a choice among three menu items, only the keys representing the numerals 1 through 3 are active. The exceptions to this are the keys <PrintScreen>, <ESC>, and <END>, which are operational at all times. The <ESC> key moves the cursor back through the menu or program to enable the user to make different selections, and the <END> key permits an immediate termination of the program at any point.

The internal checks range from simple to complex. In some cases, performing a simple mathematical calculation provides an indication of whether the desired result is difficult or impossible to achieve and triggers a CAUTION or WARNING message, respectively. For example, if the pay equation coefficients entered in program OCPLOT are incapable of producing a 100 percent pay factor under any condition, a WARNING message appears and different coefficients must be entered. In other cases, the input information may be checked against an empirically derived data base to provide appropriate guidance.

2.5 OPERATIONAL PROGRAMS

A total of eight operational programs are contained on the diskette provided with this manual. The names of the programs and brief descriptions are as follows:

Program OCPLOT enables the user with a rudimentary knowledge of statistical quality assurance to develop operating characteristic (OC) curves for either pay adjustment or pass/fail acceptance plans typically used in highway construction. The primary module is OCPLOT.EXE, and the support modules are OCMENU.EXE, OCATT.EXE, OCVAR.EXE, OCPAY.EXE, TABLEN.FIL, and TABLEPD.FIL. Program OCPLOT is described in chapter 3.

Program OCDEMO is a demonstration version of program OCPLOT. It illustrates the development of OC curves for pay adjustment acceptance procedures and runs continuously with randomly selected input values. The primary module is OCDEMO.EXE, and the support modules are TABLEN.FIL and TABLEPD.FIL. Program OCDEMO is also described in chapter 3.

Program CONCHART enables the user to construct control charts from either randomly generated data or actual field data obtained from a separate file. The primary module is CONCHART.EXE and the support module is TABLEN.FIL. Data file STRENGTH.DAT may also be used with this program but is not required. Program CONCHART is described in chapter 4.

Program CCDEMO is a demonstration version of program CONCHART. It illustrates the construction of control charts and also runs continuously with randomly selected input values. The primary module is CCDEMO.EXE, and the support modules are TABLEN.FIL and STRENGTH.DAT. Program CCDEMO is also described in chapter 4.

Program COMPSIM allows the user to experiment with computer simulation as it pertains to the testing of statistical acceptance procedures. This program illustrates in greater detail several of the techniques that underlie the development of operating characteristic curves in program OCPLOT. The primary module is COMPSIM.EXE, and the support modules are TABLEN.FIL and TABLEPD.FIL. Program COMPSIM is described in chapter 5.

Program DATATEST provides a convenient way for the user to perform an otherwise tedious statistical procedure to compare two data sets. The primary module is DATATEST.EXE, and the support modules are FTABLE.EXE and TTABLE.EXE. Program DATATEST is described in chapter 6.

Program ONETEST demonstrates the difficulty of making reliable decisions based on a single sample. The primary module is ONETEST.EXE and the support module is TABLEN.FIL. Program ONETEST is described in chapter 7.

Program PAVESAMP graphically demonstrates a stratified random sampling procedure and compares sample estimates with the true population values. The primary module is PAVESAMP.EXE, and the support modules are TABLEN.FIL and TABLEPD.FIL. Program PAVESAMP is described in chapter 8.

2.6 SUPPORT MODULES

Module TABLEN.FIL is a table of random normal numbers with mean of zero and standard deviation of one. It is used to generate random data in programs CCDEMO, COMPSIM, CONCHART, OCDEMO, OCPLOT, ONETEST, and PAVESAMP.

Module TABLEPD.FIL is a table that provides estimates of percent defective (PD) as a function of the quality index (Q) and the sample size (N). It is used with programs COMPSIM, OCDEMO, OCPLOT, and PAVESAMP.

Module FTABLE.EXE performs the function of a table of the F distribution. It is used with program DATATEST to test the hypothesis that two sample variances (or standard deviations) come from the same population.

Module TTABLE.EXE performs the function of a table of the Student t distribution. It is used with program DATATEST to test the hypothesis that two sample means come from the same population.

Module STRENGTH.DAT is a data file of concrete compressive strength tests randomly generated from a population with a mean of 5000 and a standard deviation of 300. The data set represents 200 lots, each with 5 test values, identified by lot numbers 1 through 200 and dates beginning with 1/2/94 and ending with 10/26/94. This file is accessed by program CCDEMO and may also be accessed by program CONCHART for demonstration purposes.

2.7 OBTAINING PRINTOUTS

Printouts of input menus and numerical output may be obtained at any time by pressing the <PrintScreen> key. Printouts of graphical displays may be obtained in the same manner provided the system has graphics capability, a commonly included feature with recent versions of DOS. For graphical displays, a command similar to GRAPHICS [PRINTER TYPE] must be entered from the DOS prompt before running the programs. A DOS manual should be consulted to obtain the appropriate syntax for the printer being used.

CHAPTER 3

PROGRAMS OCPLOT AND OCDEMO

3.1 OPERATING CHARACTERISTIC (OC) CURVES

One of the most important steps in the development of a statistical acceptance plan is the analysis of its operating characteristic (OC) curve. This is the only way to be certain that the acceptance procedure is capable of properly distinguishing between satisfactory and unsatisfactory work. This enables the highway agency to develop fair and effective specifications that control the risks at suitably low levels.

Even though the acceptance procedure or pay equation spells out precisely the decision to be made for any level of measured quality, there is always some degree of uncertainty in the quality measurement itself. This occurs because only a small fraction of each lot is sampled and tested, and the test procedures themselves are not perfectly repeatable. The OC curve, if constructed properly, is capable of accounting for this uncertainty.

A conventional OC curve is shown in figure 3.1. Probability of acceptance is indicated on the Y-axis for the range of quality levels indicated schematically on the X-axis. The contractor's risk of having good (AQL) work rejected and the agency's risk of accepting poor (RQL) work are both illustrated in this figure.

Figure 3.2 presents an OC curve for a statistical specification with an adjusted pay schedule. Quality levels are indicated on the X-axis in the usual manner but, instead of probability of acceptance, the Y-axis gives the expected pay factor (i.e., the long-term average pay factor).

Although the risks have a slightly different interpretation in figure 3.2, essentially the same type of information is provided. In this example, AQL work receives an expected pay factor of 100 percent, as desired, while RQL work receives an expected pay factor of 70 percent. It can also be seen in this figure that truly superior quality may receive an incentive pay factor up to a maximum of 102 percent.

The opportunity to earn at least some degree of incentive payment is necessary in order for a statistical acceptance procedure to pay an average of 100 percent when the work is exactly at the AQL. Due to the inherent variability of any sampling and testing process, some samples will underestimate the quality while others will overestimate it. Unless the acceptance procedure is designed to allow pay incentives and pay reductions to balance out in a natural way, the average pay factor will be biased downward at the AQL and acceptable work may be unfairly penalized. The failure to award an average pay factor of 100 percent at the AQL, even by only one or two percent, can result in many thousands of dollars of unwarranted pay reductions throughout the course of a construction season. The importance of including an incentive provision is illustrated in examples 3.3 and 3.4 in this chapter.

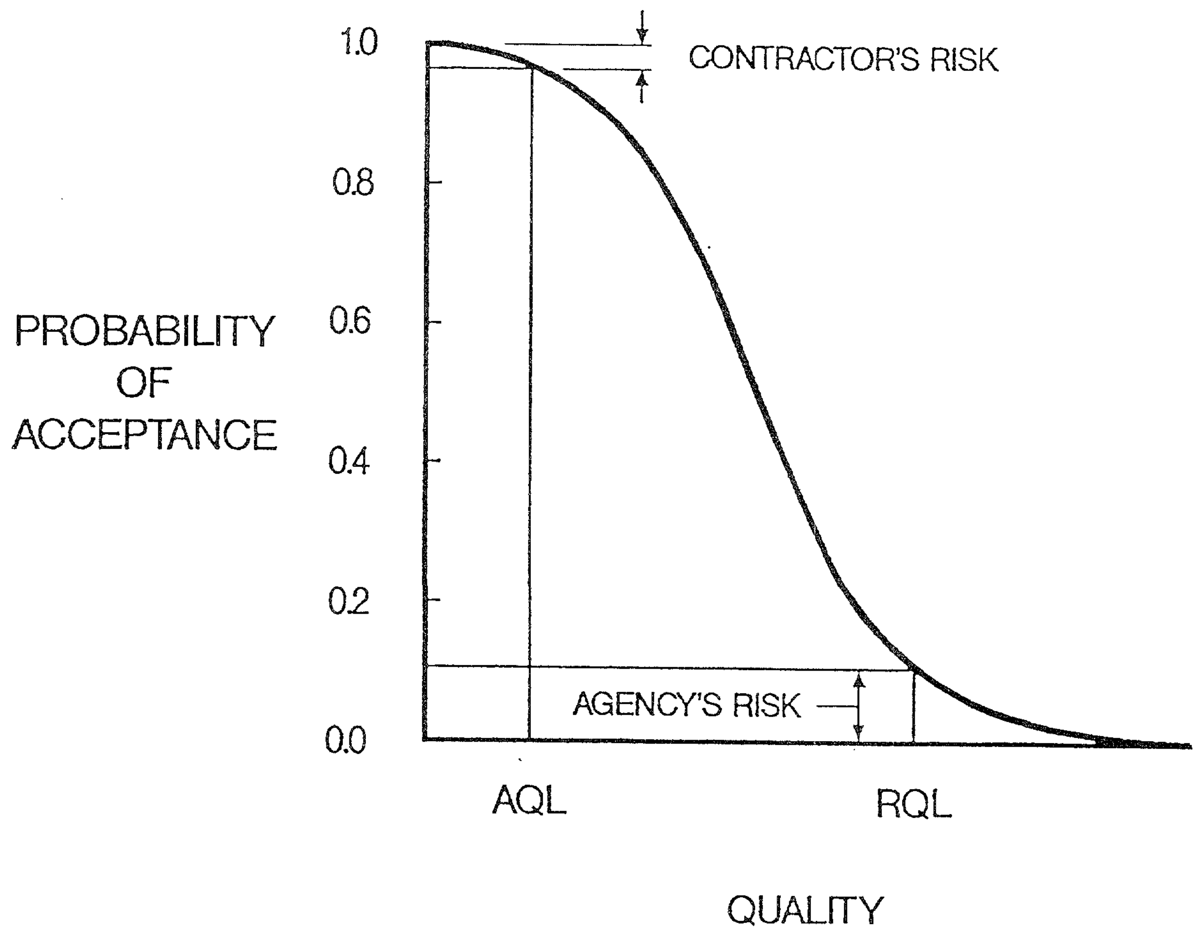


Figure 3.1. Conventional OC curve.

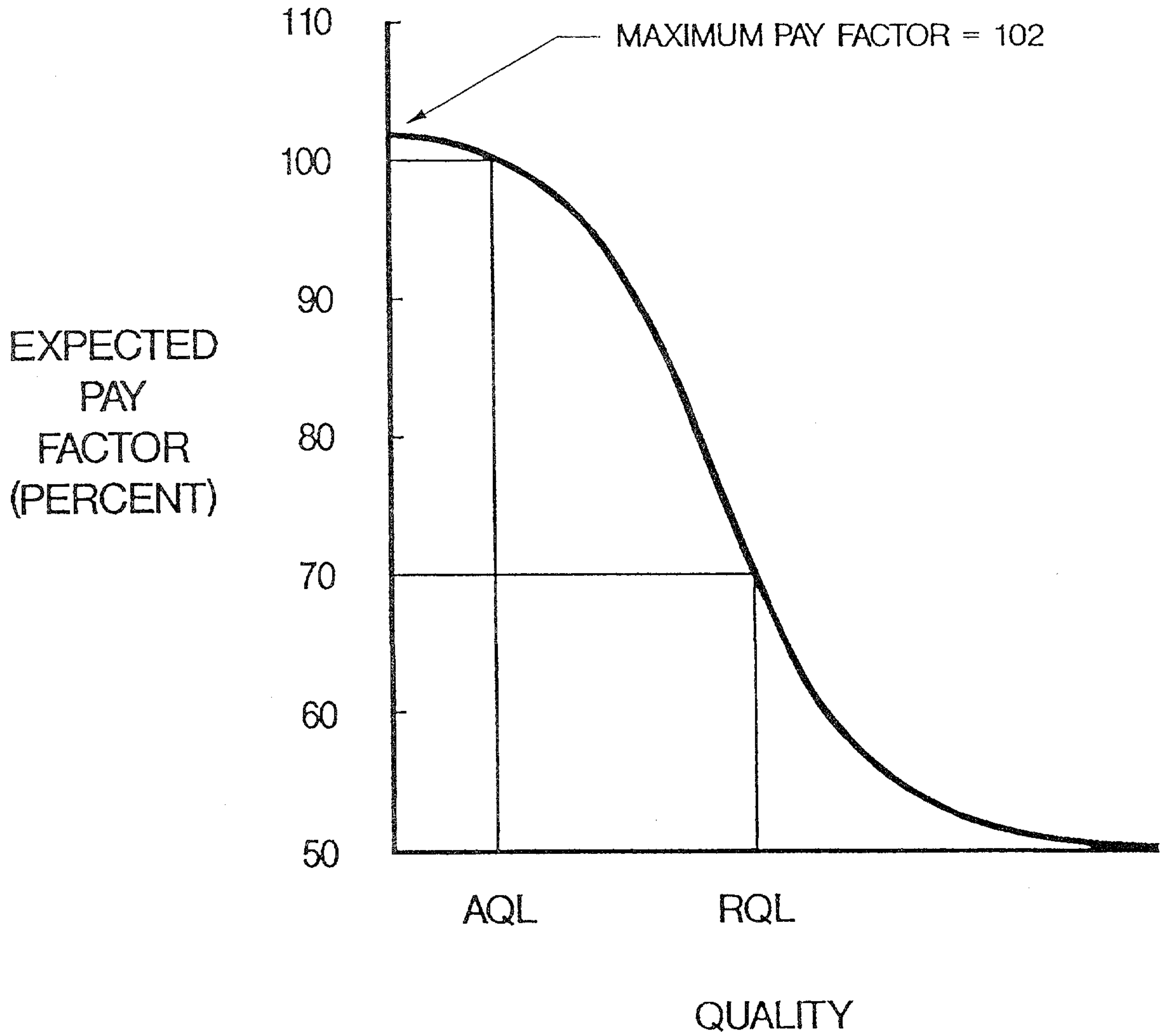


Figure 3.2. Typical OC curve for acceptance procedure with adjusted pay schedule.

3.2 METHODS OF DEVELOPING OC CURVES

In the case of pass/fail acceptance procedures, OC curves of the type shown in figure 3.1 can be computed directly or constructed with the aid of specialized mathematical tables. For acceptance procedures with adjusted pay schedules, the construction of OC curves of the type shown in figure 3.2 usually requires computer assistance. Program OCPLOT uses computer simulation to develop both types of OC curve. The use of computer simulation to analyze statistical construction specifications is discussed further in conjunction with program COMPSIM in chapter 5.

3.3 FEATURES OF PROGRAM OCPLOT

Program OCPLOT is designed to analyze the types of acceptance procedures typically used in the highway field. This includes pass/fail procedures, leading to the type of OC curve shown in figure 3.1, and pay adjustment procedures, leading to the type of OC curve shown in figure 3.2.

Figure 3.3 lists some of the options that may be selected from the primary menu. The various items appear on the screen one at a time in a logical sequence, and later items are dependent upon the responses to earlier ones. The versatility of the program is apparent from the many different ways these selections might be combined.

When the selections from the first menu are complete, the menu will appear similar to that shown in figure 3.4. The prompt "Press any key to continue" at the bottom of the display provides a pause that gives the user the opportunity to use the <ESC> key to go back and change some values or press the <PrintScreen> key if a record of the menu selections is desired. Striking almost any other key will cause the second menu in figure 3.4 to appear.

Because program OCPLOT uses computer simulation to analyze whatever acceptance procedure has been specified, it is very computationally intensive and the execution speed is dependent upon the level of precision selected from the second menu. Table 3.1 lists the number of replications performed for the different levels of precision.

Table 3.1. Program OCPLOT precision levels.

PRECISION LEVEL	NUMBER OF REPLICATIONS
1	200
2	1000
3	5000

Selection 1 provides the fastest execution, which is useful for exploratory work but may not be good enough to report as a final result. When this level is selected, 200 sample sets of the desired size are randomly generated from a normal population for each of several known levels of quality.

ACCEPTANCE METHOD
- Pass/Fail .... TYPE OF PLAN
  - Attributes
  - Variables
- Pay Adjustment

QUALITY MEASURE
- Percent Defective (PD)
- Percent Within Limits (PWL)

LIMIT TYPE
- Single-Sided
- Double-Sided

PAY EQUATION TYPE
- Linear/Nonlinear .... Enter Values

MAXIMUM PAY FACTOR
- Yes .... Enter Values
- No

ACCEPTABLE QUALITY LEVEL (AQL)
- Enter Value

REJECTABLE QUALITY LEVEL (RQL)
- Enter Value

RQL PROVISION
- Yes .... Enter RQL Pay Factor
- No

RETEST PROVISION
- Yes .... INITIAL TESTS
  - Combined
  - Discarded
- No

SAMPLE SIZE
- Enter Value(s)

Figure 3.3. Selections available in program OCPLOT.

First Menu:

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD
Pay Adjustment

QUALITY MEASURE
Percent Defective

LIMIT TYPE
Double-Sided

PAY EQUATION
PF = 102 - .2 PD

MAXIMUM PAY FACTOR
PF = 102.0

ACCEPTABLE QUALITY LEVEL
PD = 10

REJECTABLE QUALITY LEVEL
PD = 50

RQL PAY FACTOR
PD = 70

RETEST PROVISION
None

SAMPLE SIZE
10

Press any key to continue

<ESC> = Back <END> = Exit

Second Menu:

SELECT LEVEL OF PRECISION

(1) Low -- Faster Execution

(2) Intermediate

(3) High -- Slower Execution

SELECTION

<ESC> = Back <END> = Exit

Figure 3.4. First and second menus for program OCPLOT.

Each sample set is evaluated in accordance with the acceptance plan specified in the primary menu and the results are stored in memory for subsequent analysis. This is far more thorough and many times faster than testing the acceptance procedure with a field trial. (A field trial would be appropriate only if the procedure survives this initial check.)

Selection 2 from the second menu provides an intermediate level of precision for which 1000 sample sets are generated at each quality level. This level of precision is usually satisfactory to report as a final result, producing points on the OC curve representing either probability of acceptance or expected pay factor that are typically accurate to within one or two units. If still better precision is desired, selection 3 will cause 5000 sample sets to be generated at each quality level. This level of precision tends to produce a very smooth line when the OC curve is plotted.

Once the precision level is selected from the second menu, the computational process begins. For either low or intermediate precision, program OCPLOT displays detailed information at the two key points at which risk levels are usually expressed—the AQL and the RQL—as shown in figures 3.5 and 3.6. This serves two important purposes. For users less familiar with statistical estimation procedures and acceptance plans, the graphical displays at the AQL and RQL are both informative and educational. It may come as a surprise to some, for example, how widely distributed the quality estimates are, especially for small sample sizes. For users more familiar with statistical acceptance procedures, these displays provide assurance that the simulation process is working properly. The actual displays on a color monitor are color coded to clearly distinguish acceptable and rejectable test results and the corresponding pay factors.

Although the AQL and the RQL are probably the most important points at which it is desirable to know how the acceptance procedure will perform, it usually is useful to have a plot of the entire OC curve that provides a picture of the performance over the complete range of quality that might be encountered. The prompt at the bottom of the screen (not shown in figure 3.6) instructs the user to strike any key to continue with this step to obtain the display shown in figure 3.7. The X and Y axes and the two previously calculated points at the AQL and the RQL appear on the screen immediately. The remaining points appear one at a time at a speed determined by the level of precision that has been selected and the speed of the machine running the program. For a 386 machine with a math coprocessor, this may require 1 or 2 minutes when low precision is selected and 3 or 4 minutes at intermediate precision. With a 486 or faster machine there is considerably less delay.

After all the points have been calculated and plotted, the user may strike any key to connect the points with a solid line. Following this, the next key stoke will add vertical and horizontal lines highlighting the performance of the acceptance plan at the AQL and RQL, as shown in figure 3.8. And, like the histograms in figures 3.5 and 3.6, any of these displays may be printed with the <PrintScreen> key, provided the graphics capability is present.

Following this display, striking a key will produce the menu shown in figure 3.9. If the first item in this menu is selected, the output shown in figure 3.10 is displayed. This permits the user to print out the values of the data points shown in figure 3.7 from which the OC curve was constructed. The other selections in this menu make it possible to return to earlier points in the input stage of the program or to exit.

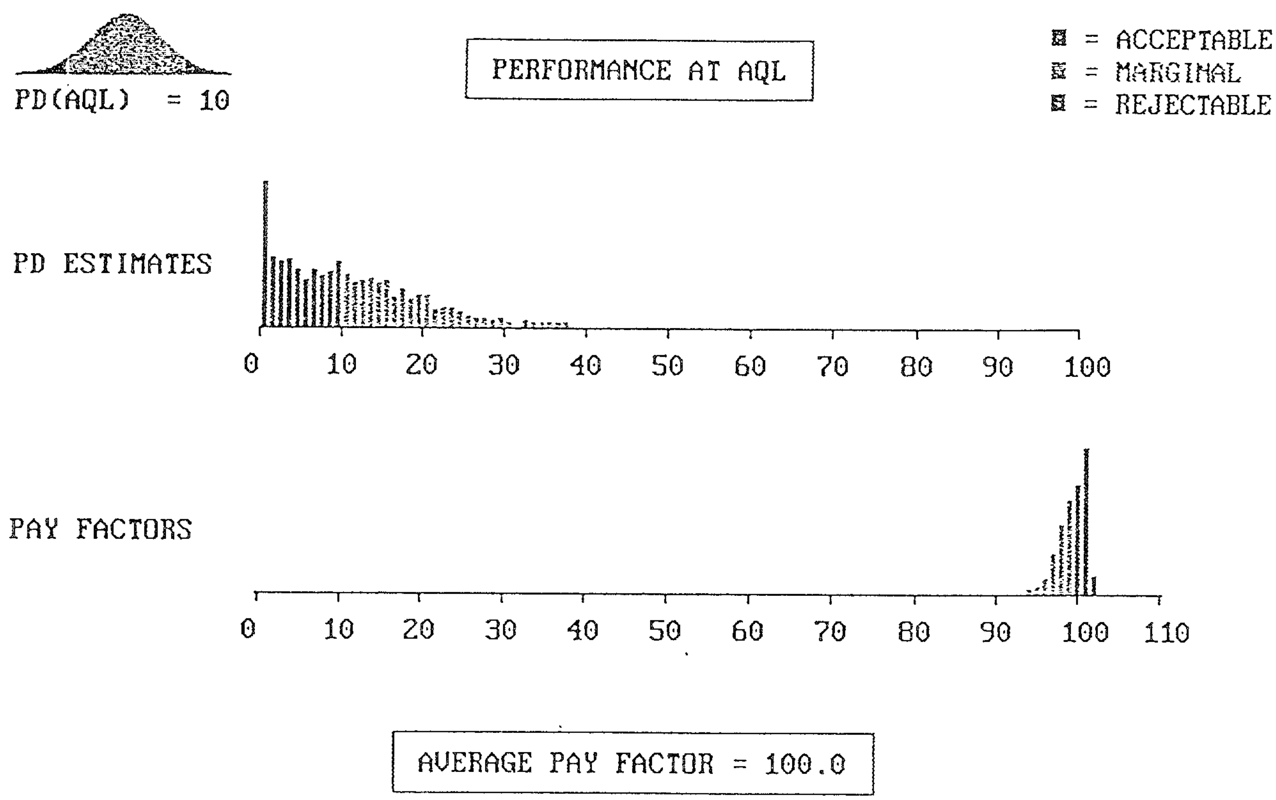


Figure 3.5. Typical display at AQL at intermediate precision by program OCPLOT.

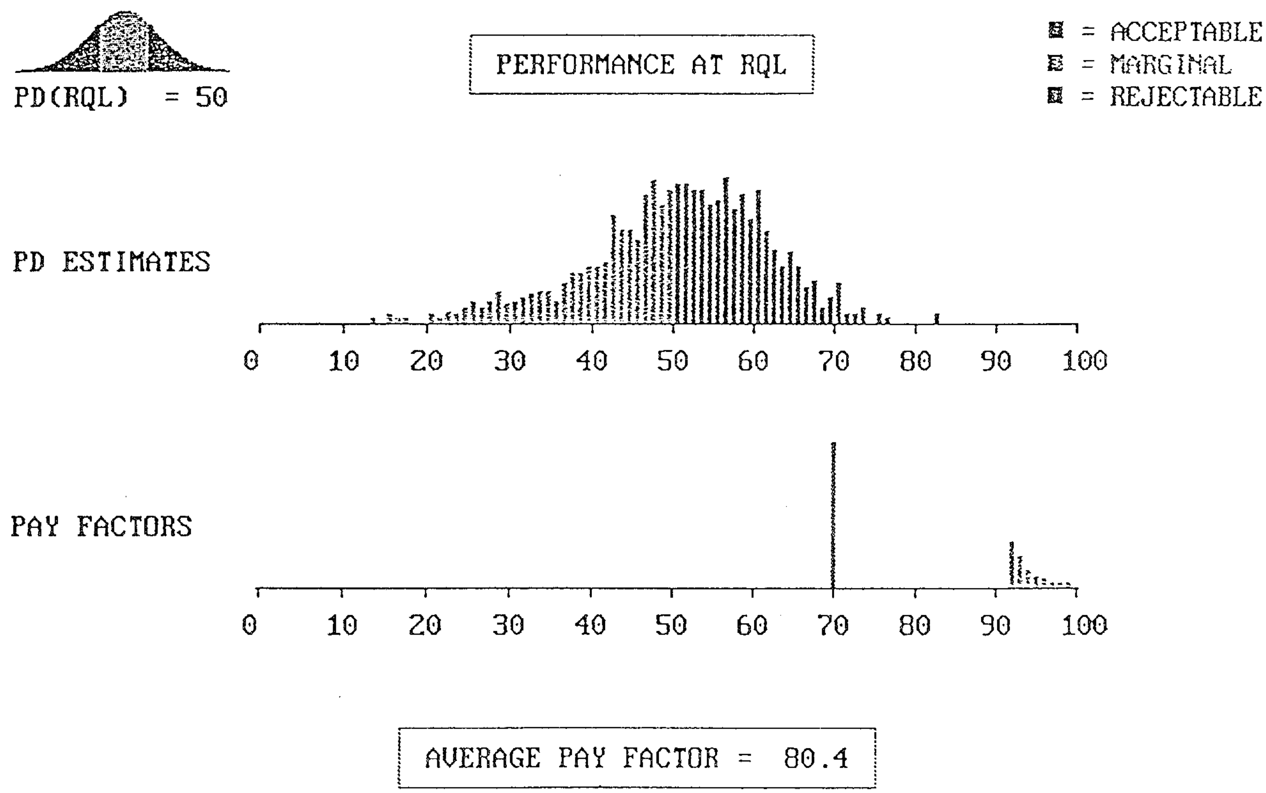


Figure 3.6. Typical display at RQL at intermediate precision by program OCPLOT.

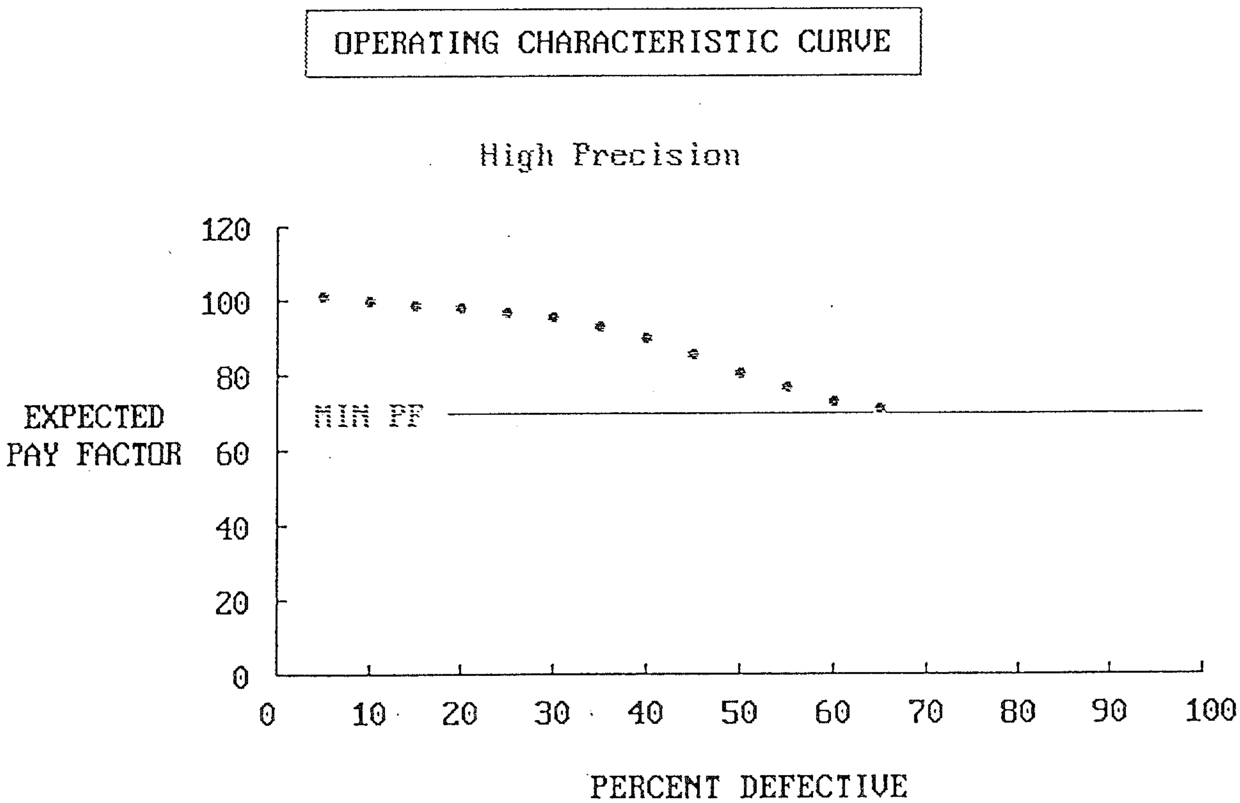


Figure 3.7. Points on OC Curve plotted by program OCPLOT.

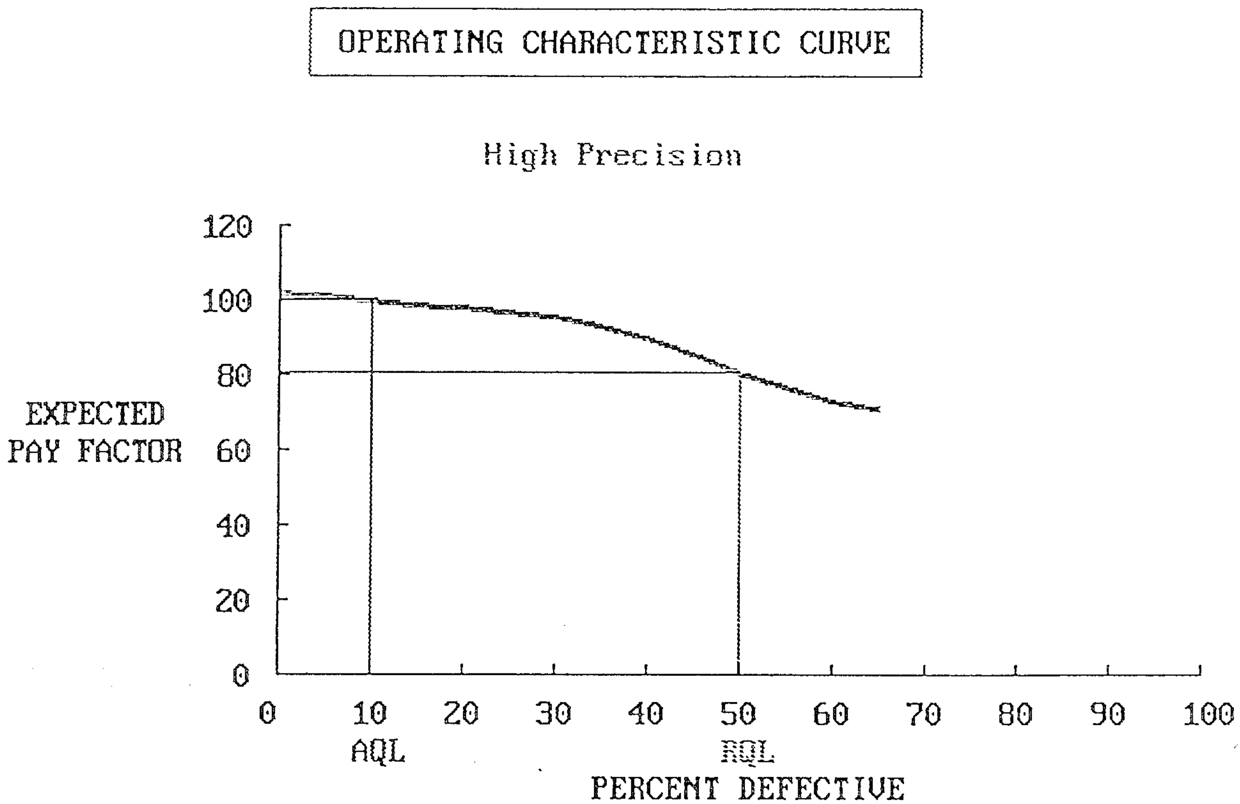


Figure 3.8. Display of OC curve by program OCPLOT
with AQL and RQL performance highlighted.

SELECTED DESIRED OPTION

(1) Display operating characteristic table
(2) Select precision level and run again
(3) Change some values and run again
(4) Run again with new imput data
(5) Exit program

SELECTION

<ESC> = Back <END> = Exit

Figure 3.9. Third menu for program OCPLOT.

PERCENT DEFECTIVE		EXPECTED PAY FACTOR
0.0		102.0
5.0		101.0
10.0	———— AQL ————	100.0
15.0		99.0
20.0		98.0
25.0		96.8
30.0		95.5
35.0		93.2
40.0		89.9
45.0		85.5
50.0	———— RQL ————	80.6
55.0		76.7
60.0		73.2
65.0		71.3

Figure 3.10. Display of numerical values of points on OC curve computed at high precision by program OCPLOT.

3.4 DEMONSTRATION PROGRAM OCDEMO

Program OCDEMO is a demonstration version of program OCPLOT that runs continuously with no input required from the user. All input selections are randomly generated within the program itself with a short time delay between each step. The various output displays remain on the screen for approximately 10 seconds before the next display appears. The random selections have been programmed in such a way that they will occasionally trigger CAUTION or WARNING messages, allowing the viewer to see many of the special features of program OCPLOT. Program OCDEMO will continue to run until it is stopped by pressing the <END> key.

3.5 EXAMPLES

PAGE

Example 3.1 -- Pass/Fail Attributes Procedure

Attributes acceptance procedures are based on measures that are counted rather than computed, such as the number of defects on an item of production or the number of test results falling outside specification limits. In contrast, variables acceptance procedures are based on statistical parameters that are computed, such as the mean and standard deviation, and lead to the estimation of percent defective or percent within limits.

Advantages of attributes procedures are that they are simple to apply and they require no assumptions about the underlying distributional form of the population being sampled. For example, a typical attributes procedure might require that a sample of size N = 10 be taken and that no more than C = 2 test results may be outside the specification limits, where "C" is referred to as the acceptance number. A disadvantage is that they require larger sample sizes to achieve the equivalent discriminating power of a variables procedure. Variables procedures, because of their inherently greater efficiency, are generally preferred whenever the requirement for a normally distributed population is reasonably satisfied.

Although the vast majority of highway construction measures tend to be normally distributed, there are some that are not. A physical constraint close to the desired target value often produces non-normality. For example, depth of cover over the top mat of reinforcing steel in a bridge deck may tend to be skewed because it is physically impossible (provided the steel is embedded) for the cover to be less than zero but there is less of a restriction on how deep the mat might be. Similarly, if the target level for percent air voids in bituminous pavement is fairly low, the physical limit of zero may tend to skew this distribution toward larger values. Another condition that can produce non-normality is the combining in the same lot of two distinctly different populations. As a general rule, a conscious effort should be made to avoid this condition when applying a statistical specification.

Because situations do arise in highway construction that warrant their use, program OCPLOT provides the capability of analyzing attributes acceptance procedures. Although it would be possible to develop a pay schedule based on an attributes procedure, their use has been limited almost exclusively to pass/fail applications. The following is presented as a generic example of such a procedure.

It is assumed for this example that the statistical quality measure is the percent defective (PD), the percentage of the lot falling outside specification limits. The acceptable quality level (AQL) and the rejectable quality level (RQL) are defined as PD = 10 and PD = 50, respectively. It is desired to develop an acceptance procedure that will balance the risks at 0.05. In other words, if the contractor provides work that is exactly at the AQL, there is to be a 0.05 chance that it will erroneously be rejected and, at the other extreme, if the work is truly at the RQL, there is to be a 0.05 chance that it will erroneously be accepted.

An acceptance plan is required, stated in terms of the sample size (N) and the acceptance number (C), that will produce the desired risks. In order for both risks to be 0.05, an OC curve is wanted that indicates probabilities of acceptance at the AQL and the RQL of P 0.95 and P 0.05, respectively. Because both N and C must be integer values, the resultant risk levels vary in discrete steps, and it usually is not possible to obtain exactly the desired risk values. To find a plan that matches the desired risk levels as closely as possible, it is necessary to examine several plans.

This can easily be accomplished with program OCPLOT by selecting "Pass/Fail" and "Attributes" from the opening menu, followed by other appropriate selections and ending with a trial combination of N and C. It is usually advantageous to make the first few runs at low precision (selected from the second menu) in order to speed up the trial-and-error process.

Figure 3.11 shows the completed menu for the initial try with N = 10 and C = 2 and figure 3.12 shows the resulting acceptance probabilities obtained at high precision. It can be seen in figure 3.12 that the probability of acceptance of 0.057 at the RQL is close to the desired value while the probability of acceptance of 0.929 at the AQL is too low.

The results of several attempts are presented in table 3.2. The values in this table were all obtained at high precision and here it can be seen that the plan having N = 13 and C = 3 comes the closest to meeting the desired acceptance probabilities of $P \geq 0.95$ and $P \leq 0.05$ at the AQL and RQL, respectively. This is a trial-and-error process but, with a little experience, it usually is possible to find a suitable plan relatively quickly.

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD Pass/Fail	REJECTABLE QUALITY LEVEL PD = 50
TYPE OF PROCEDURE Attributes	RETEST PROVISION None
QUALITY MEASURE Percent Defective	SAMPLE SIZE 10
LIMIT TYPE Single-Sided	ACCEPTANCE NUMBER 2
ACCEPTABLE QUALITY LEVEL PD = 10	

Press any key to continue

<ESC> = Back <END> = Exit

Figure 3.11. Completed menu for analysis of pass/fail attributes acceptance plan with N = 10 and C = 2.

PERCENT DEFECTIVE		ACCEPTANCE PROBABILITY
0.0		1.000
5.0		0.988
10.0	———— AQL ————	0.929
15.0		0.818
20.0		0.681
25.0		0.520
30.0		0.383
35.0		0.260
40.0		0.166
45.0		0.099
50.0	———— RQL ————	0.057
55.0		0.028
60.0		0.013

Figure 3.12. Numerical values of points on OC curve for pass/fail attributes acceptance plan with N = 10 and C = 2.

Table 3.2. Performance of attributes acceptance plans.

PERCENT DEFECTIVE (PD)	PROBABILITY OF ACCEPTANCE N = 10 C = 2	N = 12 C = 3	N = 13 C = 3	N = 14 C = 3
0	1.000	1.000	1.000	1.000
10 (AQL)	0.929	0.975	0.966	0.960
20	0.681	0.810	0.744	0.698
30	0.383	0.491	0.430	0.350
40	0.166	0.226	0.170	0.130
50 (RQL)	0.057	0.079	0.049	0.028
60	0.013	0.014	0.009	0.011

The attributes acceptance plan meeting the requirements of this example requires that a total of N = 13 samples be taken from random locations within each lot and that, after the appropriate tests have been performed, no more than C = 3 of the test results shall be outside specification limits. The use of such a plan ensures that truly AQL work will be accepted about 95 percent of the time and truly RQL work will be accepted only about 5 percent of the time.

Example 3.2 -- Pass/Fail Variables Procedure

As discussed in example 3.1, variables procedures are based on the assumption that the population being sampled is at least approximately normally distributed. They involve the computation of statistical parameters, such as the mean and standard deviation, in order to estimate percent defective or percent within limits. Provided the normality assumption is sufficiently well satisfied, variables procedures can provide essentially the same discriminating power as equivalent attributes plans but with a substantially smaller sample size.

To illustrate this last statement, a variables procedure will be sought that will have essentially the same discriminating power (OC curve) as the attributes procedure developed in example 3.1. Like the previous example, this involves a trial-and-error process with which program OCPLOT can be extremely helpful. For this example, the selections "Pass/Fail" and "Variables" are made from the opening menu, followed by other appropriate selections and ending with trial values for the sample size and acceptance limit.

This trial-and-error process proceeds more quickly if a low level of precision is selected for the initial attempts. When it appears that the appropriate combination of sample size and acceptance limit have been found, this should be checked at intermediate precision. Further minor adjustments may then be necessary before confirming the result at high precision.

Figure 3.13 shows the completed menu for the variables acceptance plan that was ultimately selected. The actual numerical values on the OC curve are shown in figure 3.14 where it can be seen that the performance of this plan very closely matches that of the attributes plan in example 3.1 (table 3.2, N = 13, C = 3). The dramatic difference is that this has been accomplished with a sample size of N = 8, whereas the attributes plan required a sample size of N = 13. In this case, which assumes that the normality assumption is satisfied, the use of a variables plan results in a direct savings in sampling and testing costs of nearly 40 percent.

Example 3.3 -- Analysis of Pay Equation

Although the pass/fail acceptance procedures discussed in examples 3.1 and 3.2 are useful for many highway construction applications, the use of acceptance procedures with adjusted pay schedules is of generally greater interest. The proper design of such plans is critical to their performance and poorly conceived plans may be either totally ineffective or impractically severe. Neither problem may be apparent, however, until the plan has been analyzed by constructing the OC curve.

A pay schedule proposed for use by an owner is given by equation 3.1. The AQL was defined as $PWL_{SPEC} = 90$ and, since there was no incentive pay provision, the maximum pay factor was limited to 100 percent.

$$PR = PWL_{SPEC} - PWL_{COMP} \tag{3.1}$$

in which

PR	=	pay reduction (percent)
PWL_{SPEC}	=	specified PWL at the AQL
PWL_{COMP}	=	PWL computed from test values

To transform this equation into a form that can be handled by program OCPLOT, it is necessary to express it in terms of the pay factor rather than the pay reduction. By substituting $PWL_{SPEC} = 90$ and $PR = 100 - PF$ into equation 3.1, equation 3.2 is obtained, subject to the restriction that $PF \leq 100$.

$$PF = 10 + PWL_{COMP} \tag{3.2}$$

in which

PF	=	pay factor (percent)
PWL_{COMP}	=	PWL computed from test values

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD
Pass/Fail

TYPE OF PROCEDURE
Variables

QUALITY MEASURE
Percent Defective

LIMIT TYPE
Single-Sided

ACCEPTABLE QUALITY LEVEL
PD = 10

REJECTABLE QUALITY LEVEL
PD = 50

RETEST PROVISION
None

SAMPLE SIZE
8

ACCEPTANCE LIMIT
PD = 26

Press any key to continue

<ESC> = Back

<END> = Exit

Figure 3.13. Completed menu for pass/fail variables acceptance plan.

PERCENT DEFECTIVE		ACCEPTANCE PROBABILITY
0.0		1.000
5.0		0.992
10.0	——— AQL ———	0.951
15.0		0.842
20.0		0.705
25.0		0.536
30.0		0.395
35.0		0.258
40.0		0.166
45.0		0.097
50.0	——— RQL ———	0.051
55.0		0.025
60.0		0.008

Figure 3.14. Numerical values of points on OC curve for pass/fail variables acceptance plan.

To judge the effectiveness of this pay equation, the OC curve will be developed for a typical sample size of N = 5. The completed input menu is shown in figure 3.15. Following this, an intermediate level of precision was selected from the second menu in order to obtain the display at the AQL shown in figure 3.16. Finally, the program was run at high precision which produced the displays shown in figures 3.17 and 3.18.

It can be seen in figure 3.16 that there is a serious problem with this acceptance procedure. A contractor who performs consistently at the AQL will receive an average pay reduction of nearly 5 percent. To emphasize the impact this would have on the construction industry, this means that a contractor responsible for $10 million worth of work under this specification over the course of a construction season would be penalized approximately $500,000 for successfully providing the level of quality that was explicitly defined as acceptable in the contract documents.

This example illustrates the situation discussed at the beginning of this chapter, whereby the failure to include an incentive pay provision with this type of specification prevents the acceptance procedure from paying an average of 100 percent when the work is exactly at the AQL. The reason for this can be seen with the help of figure 3.16. The upper histogram in this figure represents the distribution of 1000 PWL estimates, each obtained by randomly sampling a population that is exactly of AQL quality. These sample estimates range from a low of about 49 percent to a high of 100 percent because of the inherent variability of the sampling process. However, the long-term average of these estimates will always be extremely close to the true value (the AQL in this case) because the PD/PWL estimation process is an unbiased statistical estimation procedure. The problem arises because the pay schedule does not permit this unbiased property to extend to the distribution of pay factors. Because there is no incentive pay provision, all PWL estimates that are greater than the true PWL of 90 receive the maximum pay factor of 100 percent while all those below the true value receive some degree of pay reduction. Since approximately half the lots will receive pay reductions and the other half will receive 100 percent payment, the net result is that the average pay factor for AQL work will be substantially lower than 100 percent.

This situation is clearly misleading and unfair, yet it exists in many current quality assurance specifications. It is not difficult to correct, however, as will be demonstrated in the next example.

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD Pay Adjustment	ACCEPTABLE QUALITY LEVEL PWL = 90
QUALITY MEASURE Percent Within Limits	REJECTABLE QUALITY LEVEL PWL = 50
LIMIT TYPE Single-Sided	RQL PROVISION None
PAY EQUATION PF = 10 + 1 PWL	RETEST PROVISION None
MAXIMUM PAY FACTOR PF = 100	SAMPLE SIZE 5

Press any key to continue

<ESC> = Back <END> = Exit

Figure 3.15. Completed menu for analysis of pay equation.

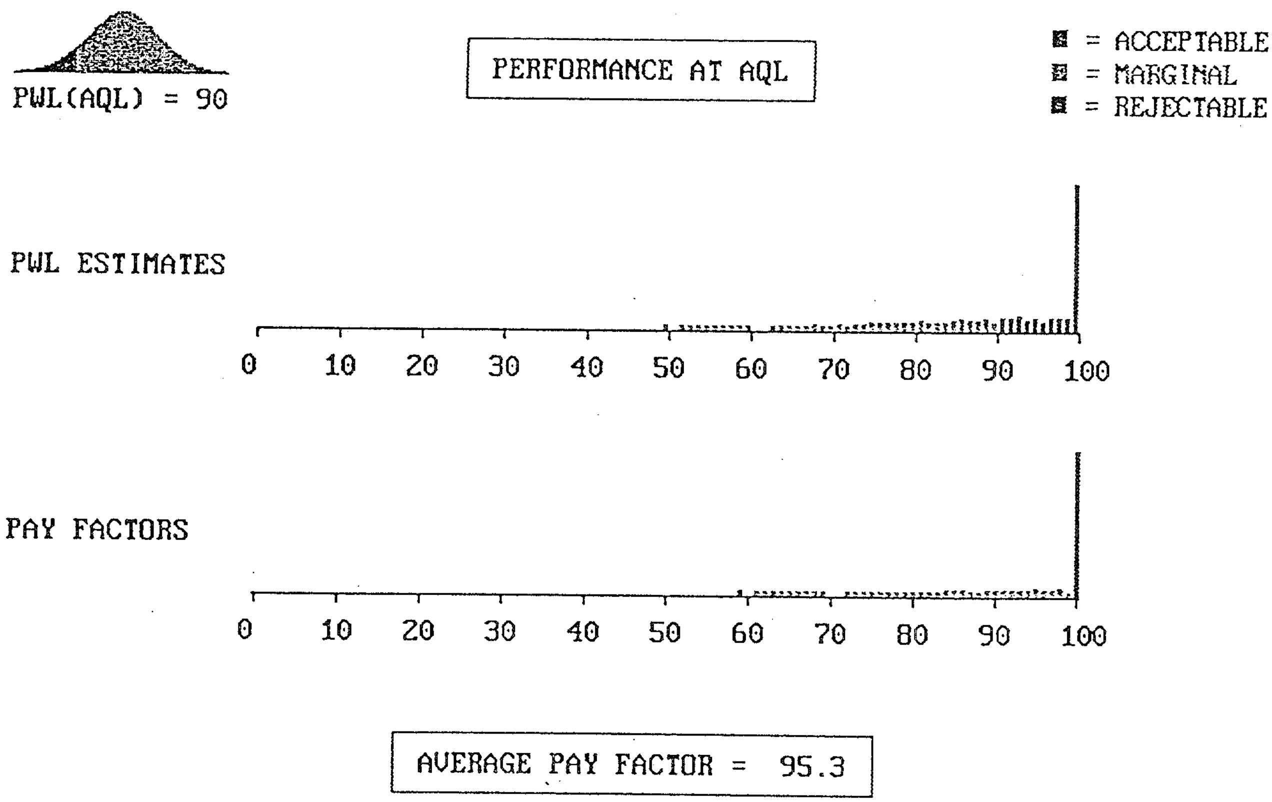


Figure 3.16. Performance of pay equation at AQL (intermediate precision).

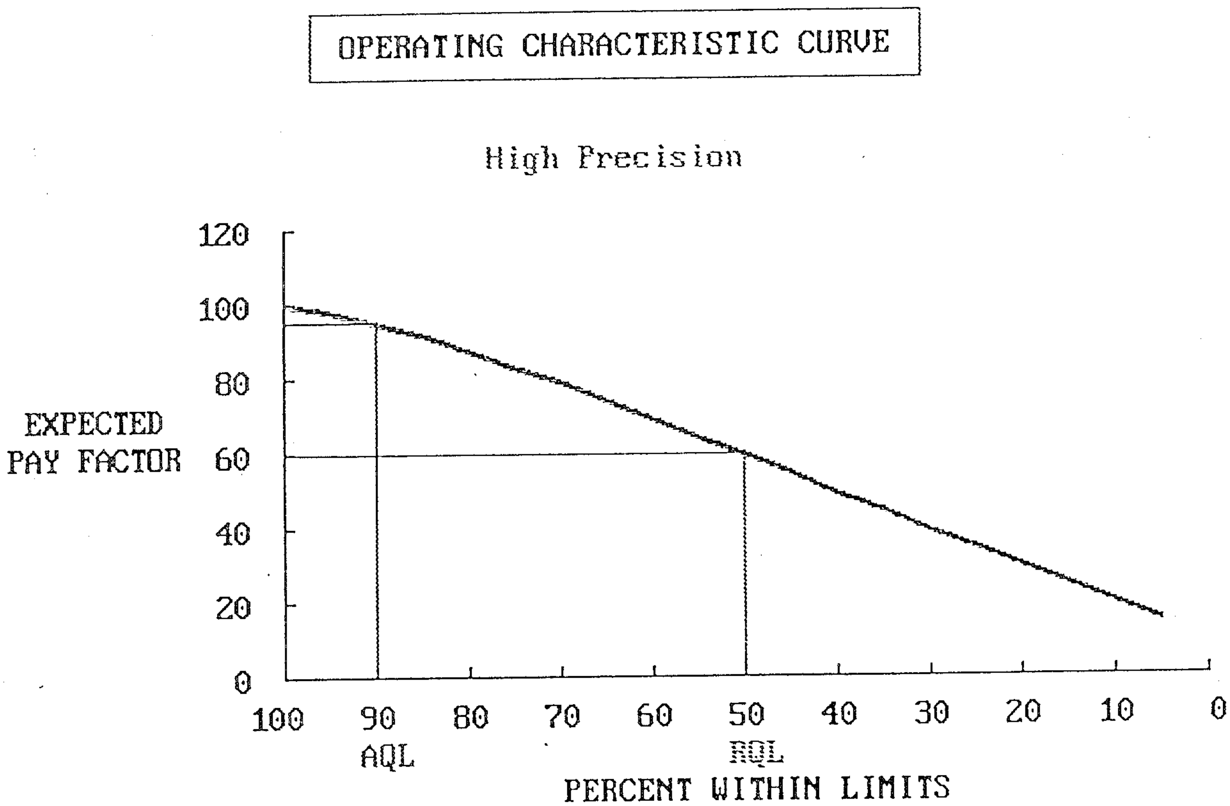


Figure 3.17. OC curve for analysis of pay equation (high precision).

PERCENT WITHIN LIMITS		EXPECTED PAY FACTOR
100.0		100.0
95.0		98.2
90.0	——— AQL ———	95.2
85.0		92.0
80.0		87.5
75.0		83.3
70.0		79.1
65.0		74.1
60.0		69.5
55.0		64.4
50.0	——— RQL ———	59.7
45.0		55.1
40.0		49.5
35.0		45.1
30.0		39.5
25.0		35.2
20.0		30.0
15.0		24.8
10.0		20.1
5.0		14.9

Figure 3.18. Numerical values of points on OC curve for analysis of pay equation (high precision).

Example 3.4 -- Effect of Incentive Pay Provision

The problem described in the preceding example, in which truly AQL work receives a substantial pay reduction, is extremely easy to correct. All that is required is the inclusion of an incentive pay provision as part of the acceptance procedure. In equation 3.2, this would mean removing the restriction that the maximum pay factor cannot exceed 100 percent.

Ordinarily, the maximum pay factor and the slope of the pay equation should be consistent with established (or estimated) performance relationships and the anticipated economic consequences of any departures from the specified AQL. To be consistent with this example, a maximum incentive pay factor of 110 percent will have to be used. In actual practice, however, most agencies have used incentive pay provisions of 105 percent or less.

To confirm that this will solve the problem, program OCPLOT was run an additional time with the identical input used for example 3.3 except that when the prompt "MAXIMUM PAY FACTOR" appeared, selection 2 was chosen, indicating that no upper limit is placed on the pay equation. The program then automatically computed and displayed the maximum pay factor of PF = 110.0, as shown in the completed menu in figure 3.19. The performance at the AQL is displayed in figure 3.20, where it is seen that the expected pay factor is almost exactly 100 percent, as desired.

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD Pay Adjustment	ACCEPTABLE QUALITY LEVEL PWL = 90
QUALITY MEASURE Percent Within Limits	REJECTABLE QUALITY LEVEL PWL = 50
LIMIT TYPE Single-Sided	RQL PROVISION None
PAY EQUATION PF = 10 + 1 PWL	RETEST PROVISION None
MAXIMUM PAY FACTOR PF = 110.0	SAMPLE SIZE 5

Press any key to continue

<ESC> = Back <END> = Exit

Figure 3.19. Completed menu for analysis of acceptance procedure with incentive pay provision.

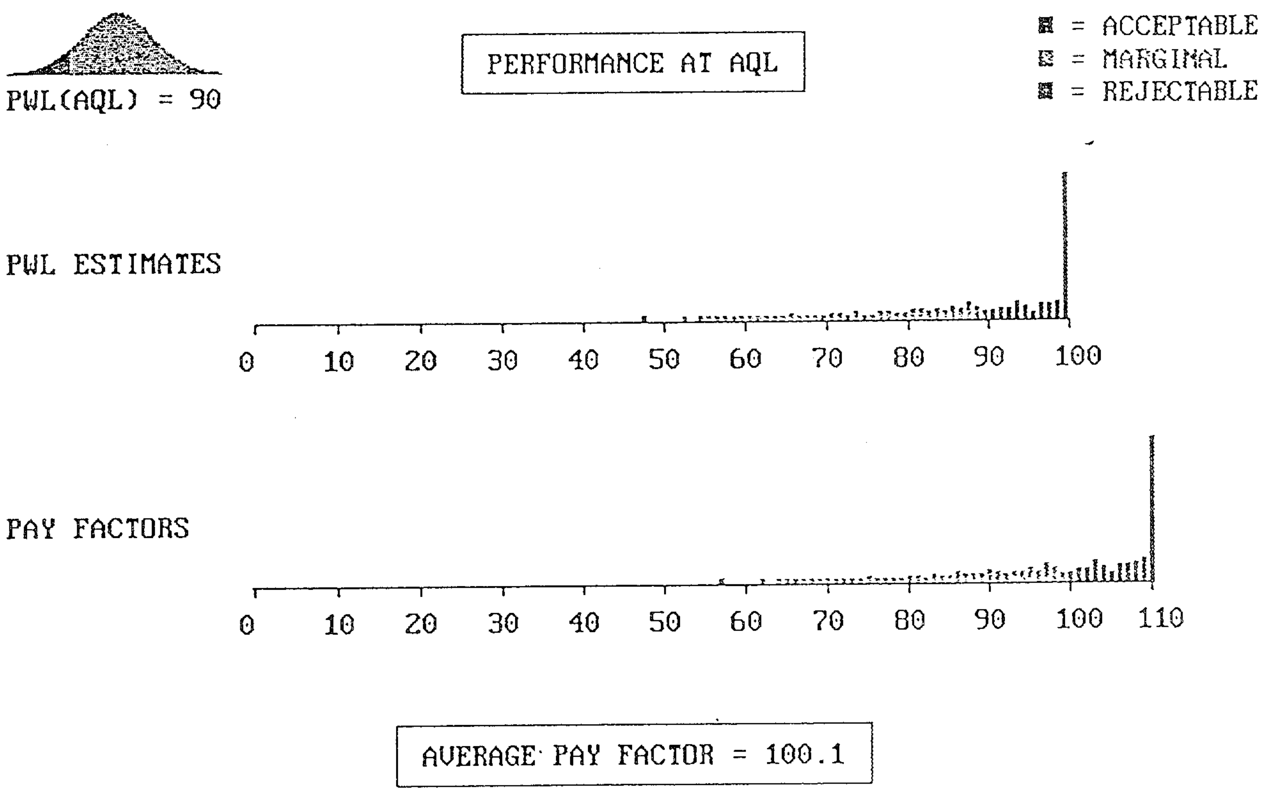


Figure 3.20. Performance at AQL of acceptance procedure with incentive pay provision.

Example 3.5 -- Analysis of Stepped Pay Schedule (LINEAR CASE)

Although designed specifically to analyze pay equations, program OCPLOT can often be used to obtain a reasonably accurate OC curve for a stepped pay schedule. To do this, it is first necessary to find a pay equation that approximates the stepped pay schedule. This can be accomplished by plotting the stepped pay schedule and then fitting an approximate pay equation. A suitable linear pay equation can often be fitted by eye. When obtained in this manner, the slope of the equation is computed by selecting two points on the line and dividing the spread on the Y-axis by the spread on the X-axis. The constant term of the equation is simply the Y intercept.

Table 3.3 presents a stepped pay schedule typical of many that have been used for highway construction. This particular schedule, based on PD as the quality measure, awards an incentive pay factor of 102 percent when PD $\leq$ 5 and pays a minimum of 70 percent when PD $\geq$ 40.

Table 3.3. Stepped pay schedule for Example 3.5.

PERCENT DEFECTIVE (PD)	PAY FACTOR (Percent)
$\leq$ 5.00	102
5.01 - 9.99	100
10.00 - 19.99	95
20.00 - 39.99	85
$\geq$ 40.00	70

The pay schedule in table 3.3 is plotted in figure 3.21 and a straight line has been drawn through the steps in such a way that the areas above and below the line are approximately equal. Two points on this line are (PD = 0, PF = 102) and (PD = 40, PF = 81) and the slope is computed to be (81 - 102)/(40 - 0) = -0.53. The constant term is the Y-intercept of 102, and the complete pay equation is given by equation 3.3. The pay factor is set to the minimum value of PF = 70 percent whenever the percent defective estimate exceeds PD = 40, the same as with the stepped pay schedule.

$$PF = 102 - 0.53\ PD \qquad (3.3)$$

Figure 3.22 shows the menu selections in program OCPLOT to obtain the OC curve for this pay equation and figure 3.23 gives the numerical values on the OC curve. In order to determine the accuracy of this approach, a separate computer program (not provided on the Demonstration Project 89 diskette) was written that directly evaluated the stepped pay schedule in table 3.3 at the same sample size of N = 5. The results of these two methods are presented in table 3.4, where it can be seen that there is extremely close agreement.

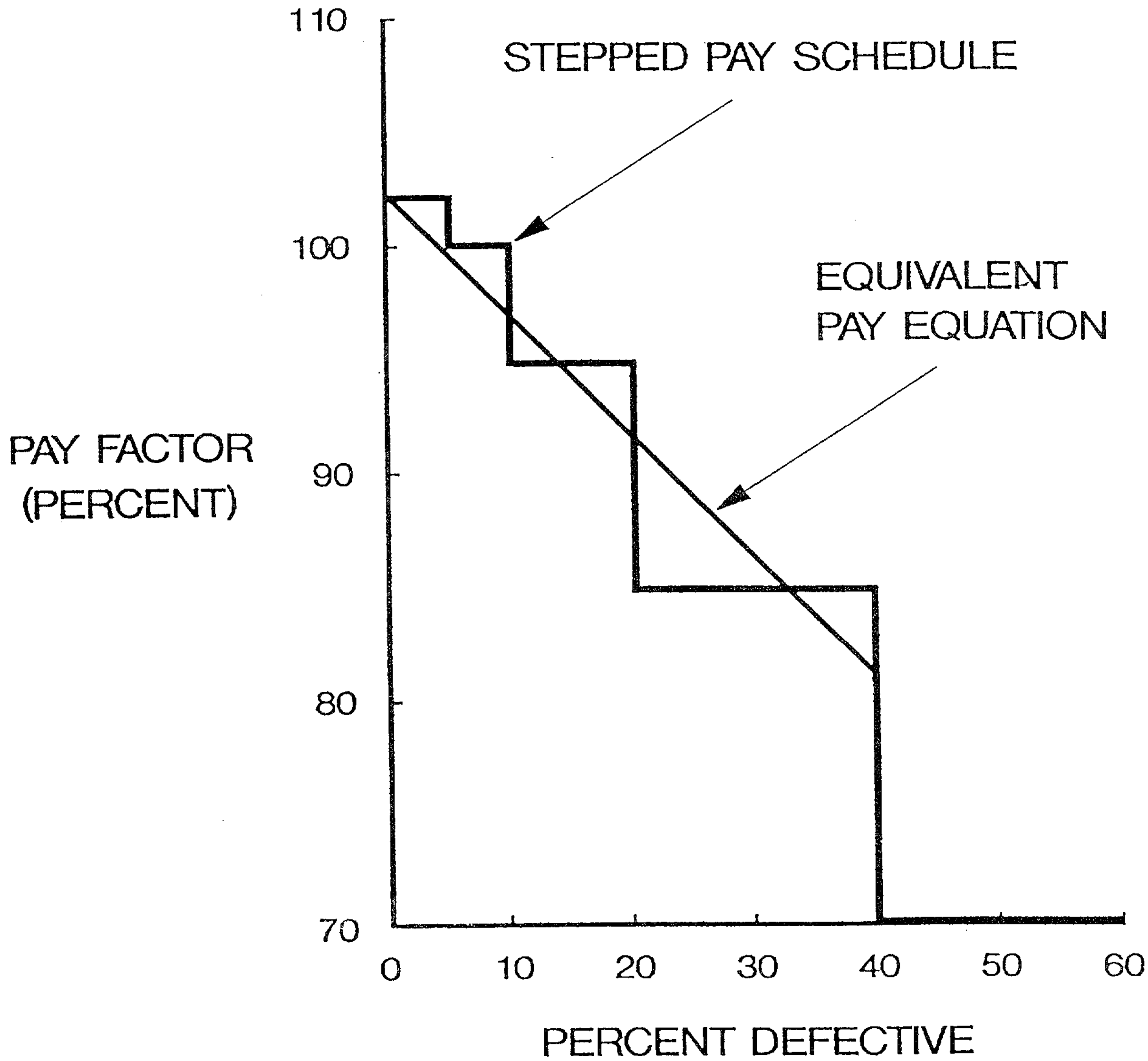


Figure 3.21. Stepped pay schedule and equivalent pay equation.

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD
Pay Adjustment

QUALITY MEASURE
Percent Defective

LIMIT TYPE
Single-Sided

PAY EQUATION
PF = 102 - .53 PD

MAXIMUM PAY FACTOR
PF = 102

ACCEPTABLE QUALITY LEVEL
PD = 10

REJECTABLE QUALITY LEVEL
PD = 40

RQL PAY FACTOR
PF = 70

RETEST PROVISION
None

SAMPLE SIZE
5

Press any key to continue

<ESC> = Back

<END> = Exit

Figure 3.22. Completed menu to evaluate equivalent pay equation.

PERCENT DEFECTIVE		EXPECTED PAY FACTOR
0.0		102.0
5.0		99.3
10.0	——— AQL ———	96.5
15.0		93.9
20.0		90.7
25.0		87.8
30.0		84.7
35.0		81.9
40.0	——— RQL ———	79.0
45.0		77.0
50.0		74.7
55.0		73.2
60.0		72.0
65.0		71.2

Figure 3.23. Numerical values of points on OC curve for equivalent pay equation.

Table 3.4 Comparison of OC curves obtained by two methods.

	EXPECTED PAY FACTOR (PERCENT)	
PERCENT DEFECTIVE (PD)	PAY SCHEDULE PROGRAM	APPROXIMATION WITH PROGRAM OCPLOT
10	96.6	96.5
20	90.7	90.7
30	84.5	84.7
40	79.3	79.0
50	74.9	74.7
60	72.1	72.0

There are two conclusions that can be drawn from this example. One is that a reasonably accurate OC curve can be obtained by fitting a pay equation by eye to a stepped pay schedule and analyzing it with program OCPLOT. The other is that stepped pay schedules and pay equations can produce essentially the same result over an extended period of time. Pay equations, however, have an inherent advantage in that they tend to avoid potential disputes over measurement precision and round-off rules that can occur when a quality estimate falls close to a boundary in a stepped pay schedule.

Example 3.6 -- Analysis of Stepped Pay Schedule (NONLINEAR CASE)

Example 3.3 presented a pay schedule that might at first glance have appeared to be suitable but which was found to be unduly harsh, paying well below 100 percent for work that was truly satisfactory. Example 3.6 illustrates the opposite case. In both cases, it is important to recognize that the true performance of the acceptance procedures becomes apparent only when the OC curves are constructed.

Example 3.5 demonstrated that a reasonably accurate OC curve can be obtained by approximating the stepped pay schedule with a linear pay equation. Example 3.6 illustrates a case for which a nonlinear equation is required.

Program OCPLOT provides the capability to analyze two types of nonlinear pay equation, given by equations 3.4 and 3.5, in which the symbol "^" indicates that the term that follows is an exponent.

$$PF = A - B * PD \wedge C \quad (3.4)$$

$$PF = A + B * PWL \wedge C \quad (3.5)$$

in which

PF	=	pay factor (percent)
PD	=	percent defective
PWL	=	percent within limits
A, B, C	=	constant terms in the equation

Although pay schedules with large steps can cause administrative problems as noted at the end of the previous example, a pay schedule with many small steps will perform nearly the same as a pay equation. One such pay schedule that had been proposed is presented in table 3.5 (shown here only for the single sample size of N = 5). It was based on PWL, defined the AQL as PWL = 95, and allowed incentive pay factors up to a maximum of 105 percent.

Table 3.5. Stepped pay schedule for Example 3.6.

PERCENT WITHIN LIMITS (PWL)	PAY FACTOR (PERCENT)	PERCENT WITHIN LIMITS (PWL)	PAY FACTOR (PERCENT)
100	105	59	89
92	104	57	88
87	103	56	87
83	102	55	86
80	101	53	85
78	100	52	84
75	99	51	83
72	98	50	82
71	97	48	81
69	96	47	80
68	95	46	79
66	94	45	78
65	93	43	77
63	92	42	76
62	91	41	75
60	90		

When plotted against decreasing PWL, the pay factors in Table 3.5 curve downward in an approximately parabolic shape. This suggests that one of the nonlinear pay equation forms in program OCPLOT will be appropriate. By experimenting with the two equation forms, it quickly becomes apparent that the curve will be easier to fit if it is based on PD rather than PWL. Therefore, the curve will be of the form given by equation 3.4.

An advantage of this form of the equation is that it can be determined by inspection that A = 105, the maximum pay factor, since this is the Y-intercept of the equation. By taking logs of both sides of equation 3.4, equation 3.6 is obtained.

$$\ln (105 - PF) = \ln B + C \ln PD \quad (3.6)$$

The points (PD = 80, PF = 101) and (PD = 50, PF = 82) obtained from table 3.5 are used with equation 3.6 to develop two simultaneous equations in two unknowns. These are then solved to give B = 0.0131 and C = 1.91, and the resulting equivalent pay schedule is given by equation 3.7. Table 3.6 demonstrates that this equation provides a very close approximation of the stepped pay schedule in table 3.5.

$$PF = 105 - 0.0131\ PD \wedge 1.91 \quad (3.7)$$

The next step is to run program OCPLOT with this pay equation to obtain the OC curve. The completed input menu is shown in figure 3.24. The RQL is entered as PD = 57 instead of PD = 60 because the fitted pay equation drops to the minimum pay factor of PF = 75 (actually 75.4) at PD = 57.

The resulting OC curve is shown in figure 3.25 where a problem is immediately apparent. It can be seen from this figure that the expected pay factor at the AQL is well above 100 percent. Other displays, not shown in this example, indicate that it is about 104 percent.

This is a significant finding. It is unlikely that any agency would want to use an acceptance plan that provides this degree of overpayment at the AQL and, as the result of a more accurate analysis performed earlier, this acceptance procedure was substantially revised. This illustrates in a dramatic way the value of constructing the OC curve as part of the specification development process so that problems of this nature can be detected and corrected prior to implementation.

Example 3.7 -- Specification Development Process

This example outlines the steps of the specification development process that will enable the user of program OCPLOT to develop a statistical acceptance procedure with a pay schedule suitable for any specific application.

Step 1. Select the quality measure that is to be used. This should be a measure known to be related to performance—such as compressive strength of portland cement concrete, air voids content or density of bituminous concrete, or thickness of pavement—and for which well established and reliable test methods are known to exist. For this example, no selection is made so that the resulting acceptance procedure and pay equation may be regarded as a generic SQA specification.

Table 3.6. Comparison of stepped pay schedule and equivalent nonlinear pay equation.

STEPPED PAY SCHEDULE			EQUIVALENT PAY EQUATION:
PWL	PD	PF	PF = 105 - 0.0131 PD ^ 1.91
100	0	105	105.0
92	8	104	104.3
87	13	103	103.2
83	17	102	102.1
80	20	101	101.0
78	22	100	100.2
75	25	99	98.9
72	28	98	97.4
71	29	97	96.9
69	31	96	95.8
68	32	95	95.2
66	34	94	94.0
65	35	93	93.3
63	37	92	92.0
62	38	91	91.4
60	40	90	90.0
59	41	89	89.2
57	43	88	87.7
56	44	87	87.0
55	45	86	86.2
53	47	85	84.5
52	48	84	83.7
51	49	83	82.8
50	50	82	82.0
49	51	81	81.1
47	53	80	79.3
46	54	79	78.3
45	55	78	77.4
43	57	77	75.4
42	58	76	74.4
41	59	75	73.4

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD Pay Adjustment	ACCEPTABLE QUALITY LEVEL PD = 5
QUALITY MEASURE Percent Defective	REJECTABLE QUALITY LEVEL PD = 57
LIMIT TYPE Single-Sided	RQL PAY FACTOR PF = 75
PAY EQUATION PF = 105 - .0131 PD ^ 1.91	RETEST PROVISION None
MAXIMUM PAY FACTOR PF = 105.0	SAMPLE SIZE 5

Press any key to continue

<ESC> = Back <END> = Exit

Figure 3.24. Completed menu for analysis of equivalent nonlinear pay equation.

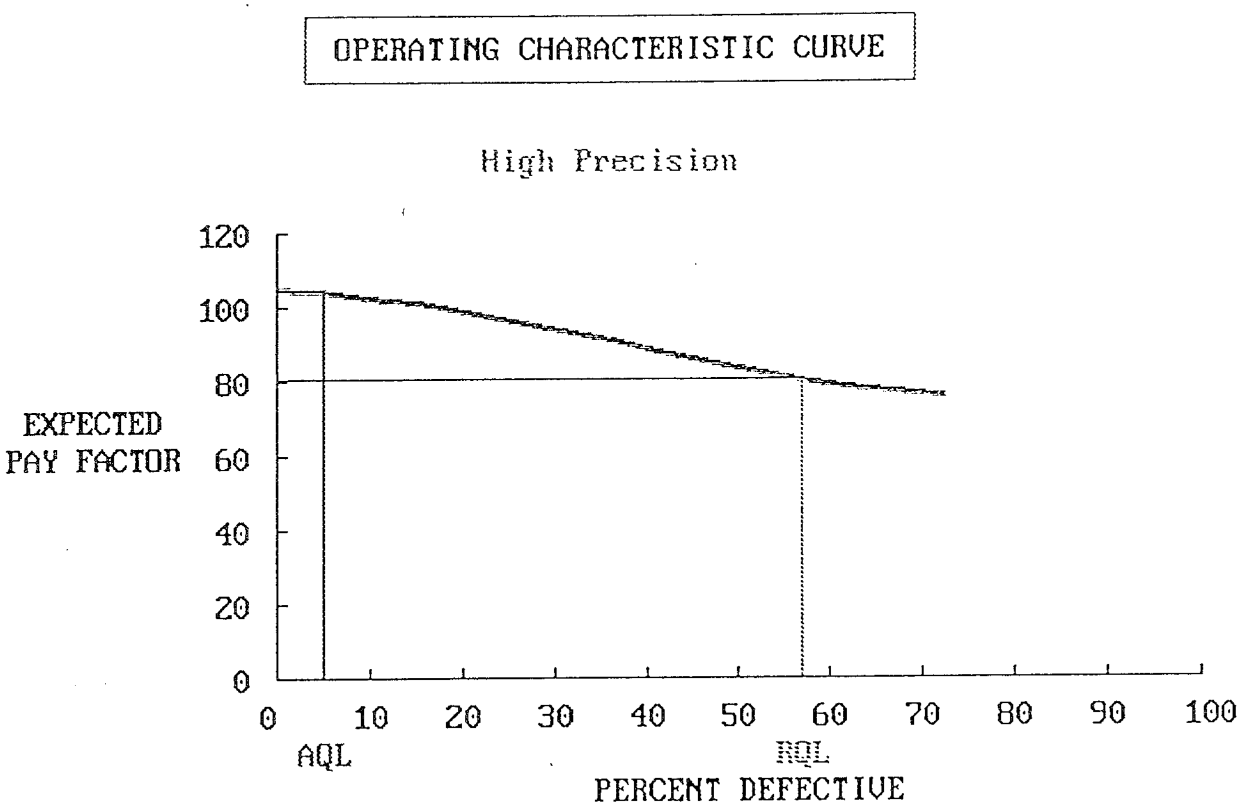


Figure 3.25. OC curve produced by nonlinear pay equation.

Step 2. Select the statistical measure of quality to be used. In recent years, there has been a tendency to use either percent defective (PD) or percent within limits (PWL) because these measures simultaneously control both the average level and the variability of the work in a statistically efficient way. The two measures are exactly equivalent, it is strictly a matter of preference which one is used, and program OCPLOT has been written to accommodate either approach. Pay equations based on both measures will be developed for this example.

Step 3. In order to communicate to the contractor exactly what is required, it is necessary to define the acceptable quality level (AQL), that level of quality that will be regarded as completely acceptable. For this example, it is assumed that the highway agency has data showing that as much as 10 percent of the work may be outside specification limits without the occurrence of noticeable performance problems and that it is desired to develop a specification that will continue to accept this level of quality. Therefore, the AQL will be defined as PD = 10 percent defective. When the pay equation is developed and the OC curve is checked in Step 9, it will be required that AQL quality receive an average pay factor of 100 percent.

Step 4. To protect against seriously defective work, a rejectable quality level (RQL) must also be defined. This provides a decision point at which the highway agency reserves the option to require removal and replacement, corrective action, or the assignment of a minimum pay factor for the lot. As a general rule, RQL values must be set at sufficiently low levels of quality that such drastic action is truly warranted and defensible. For this example, it is assumed that the specification is being written for some pavement characteristic that does not pose a major safety hazard and that the highway agency has data showing that a significant shortening of service life occurs when 75 percent or more of the work is outside specification limits. Consequently, the decision is made to define the RQL as PD = 75 percent defective.

Step 5. The justification for withholding payment for deficient quality should be based on the anticipated future costs associated with reduced performance or loss of service life resulting from the quality deficiency. Through various performance relationships available to pavement designers, it is possible to estimate the loss in service life resulting from substandard quality. This can be combined with life-cycle cost analysis techniques to estimate an approximate present-worth cost associated with specific levels of deficient quality. For this example, it is assumed that the shortening of service life at the RQL discussed in step 4 corresponds to a loss of 40 percent of the in-place cost of the item of construction. This justifies an average pay level of 60 percent whenever the highway agency waives the option to require removal and replacement of RQL work. When the pay schedule is developed and the OC curve is constructed in step 9, it will be required that RQL quality receive an average pay factor of approximately 60 percent.

Step 6. It must be decided if an incentive pay provision is to be included and, if so, of what magnitude. The withholding of payment to cover the added costs of deficient quality, discussed in step 5, implies that there also would be monetary benefits associated with increased quality. Furthermore, it was demonstrated in examples 3.3 and 3.4 that some degree of incentive pay provision is necessary in order for the pay equation to fairly pay an average of 100 percent at the AQL. For this example, it is assumed that the highway agency has concluded that superior work of greater than AQL quality leads to enhanced performance and extended service life, that there are no other modes of failure that would negate these benefits, and that the appropriate maximum incentive pay factor is 105 percent for work that is estimated to be zero percent defective.

Step 7. At some point in the development of a statistical specification, it is necessary to define lot size. This is dictated primarily by practicality and convenience except that, for variables acceptance procedures, care must be exercised in combining work produced at different times or under different conditions because this might violate the assumption of a normally distributed population. Although the definition of lot size has no direct effect on the analysis of the acceptance procedure, it does have an indirect effect. If the number of random samples that can practically be taken from a single lot do not produce a sufficiently discriminating OC curve in step 9, then a feasible solution is to increase the lot size in order to provide a larger sample size.

Step 8. A decision must be made regarding the inclusion of a retest provision and, if there is one, how the retest values are to be treated. A retest might be included (a) to confirm that an RQL indication is correct before requiring removal and replacement or assigning a minimum pay factor, (b) to produce a more desirable OC curve that properly balances the risks between the highway agency and the contractor, (c) to make more efficient use of limited sampling and testing resources by permitting acceptance on the basis of relatively few tests when quality is running at consistently high levels, or (d) to guard against a breakdown in any of the steps of the sampling and testing process. If a retest provision is to be used, it must be described explicitly in the contract documents, including whether or not the retest results are to be combined with the initial test results or used by themselves to make the final determination of acceptance. For this example, it is assumed that the highway agency has elected not to include a retest provision.

Step 9. The next step is perhaps the most critical in the specification development process: the analysis of the acceptance procedure to confirm that it will perform effectively and fairly. Trial values for the pay equation coefficients, the RQL pay factor, and the sample size are entered in the primary menu of program OCPLOT to see if these choices produce a suitable OC curve. The suitability of the OC curve will be judged on the basis of the decisions made in steps 3 through 6 which are summarized in table 3.7.

Table 3.7. Desired OC curve values for Example 3.7.

PERCENT DEFECTIVE (PD)	DESIRED AVERAGE PAY FACTOR (PERCENT)
0	105
10	100
75	60

For the vast majority of cases, a linear pay equation will be found to be sufficient. For PD as the statistical quality measure, program OCPLOT uses the form presented in equation 3.8.

$$PF = A - B * PD \tag{3.8}$$

in which

PF	=	pay factor (percent)
PD	=	percent defective
A, B	=	equation coefficients

An advantage of selecting PD rather than PWL as the quality measure upon which to develop the pay equation is that this allows coefficient A to simply be set equal to 105, the maximum incentive pay factor. Then, since it is desired for the pay equation to produce an average pay factor of 100 percent when the quality level is truly at the AQL of PD = 10, a logical first choice for coefficient B can be obtained by substituting these values into equation 3.8 and solving for B. This produces A = 105 and B = 0.5, and the trial pay equation to be evaluated with program OCPLOT is given by equation 3.9.

$$PF = 105 - 0.5\ PD \tag{3.9}$$

Equation 3.10 is the equivalent pay equation in terms of PWL as the quality measure. This is obtained by substituting PD = 100 - PWL into equation 3.9.

$$PF = 55 + 0.5\ PWL \tag{3.10}$$

Next, a trial value for the RQL pay factor must be selected which represents the minimum pay factor to be assigned whenever RQL work is allowed to remain in place. Because the desired average pay factor at the RQL is 60 percent, it might be thought that this is the appropriate value to enter in the menu. However, if the acceptance procedure were written so that a pay factor of 60 percent was assigned whenever RQL work was detected, a truly RQL condition would cause this to happen only about half the time because about half of the quality estimates will overestimate the true quality level while the other half will underestimate it. As a result, about half the pay factors would be greater than 60 percent and the average pay factor would be substantially larger than 60 percent. (This is similar to the situation at the AQL demonstrated in example 3.3 for which the average pay factor was less than the desired value of 100 percent.) Consequently, a somewhat lower value must be chosen as the RQL pay factor. For this trial run, a value of PF = 50 will be used.

Finally, a trial sample size must be selected. A typical value of N = 5 will be used and the completed menu is shown in figure 3.26.

Figures 3.27 and 3.28 show the histograms of the quality estimates and the pay factors at the AQL and the RQL, obtained at intermediate precision with 1000 randomly generated lots at each quality level. It can be seen in these figures that, for all practical purposes, the desired results at

ENTER THE FOLLOWING INFORMATION

ACCEPTANCE METHOD Pay Adjustment	ACCEPTABLE QUALITY LEVEL PD = 10
QUALITY MEASURE Percent Defective	REJECTABLE QUALITY LEVEL PD = 75
LIMIT TYPE Single-Sided	RQL PAY FACTOR PF = 50
PAY EQUATION PF = 105 - .5 PD	RETEST PROVISION None
MAXIMUM PAY FACTOR PF = 105.0	SAMPLE SIZE 5

Press any key to continue

<ESC> = Back <END> = Exit

Figure 3.26. Completed menu for specification development process in Example 3.7.

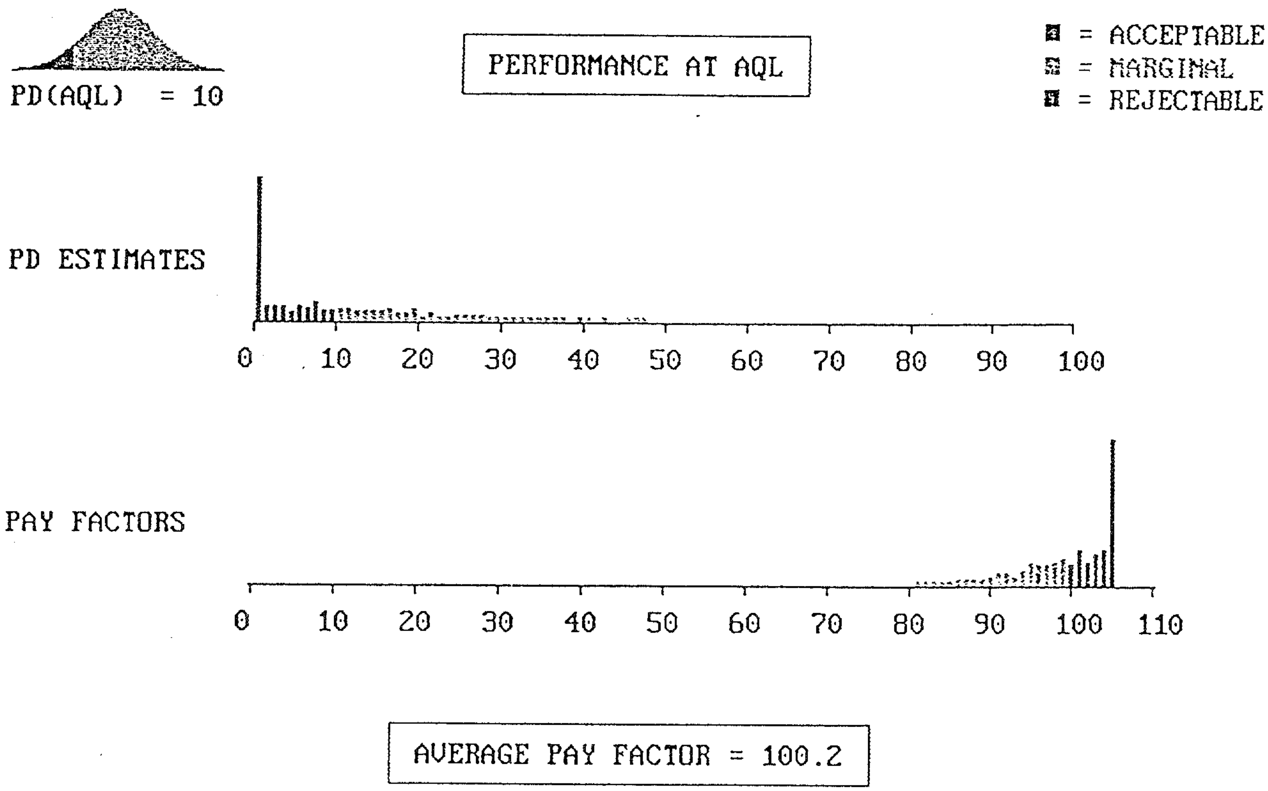


Figure 3.27. Performance at AQL of acceptance procedure developed in Example 3.7.

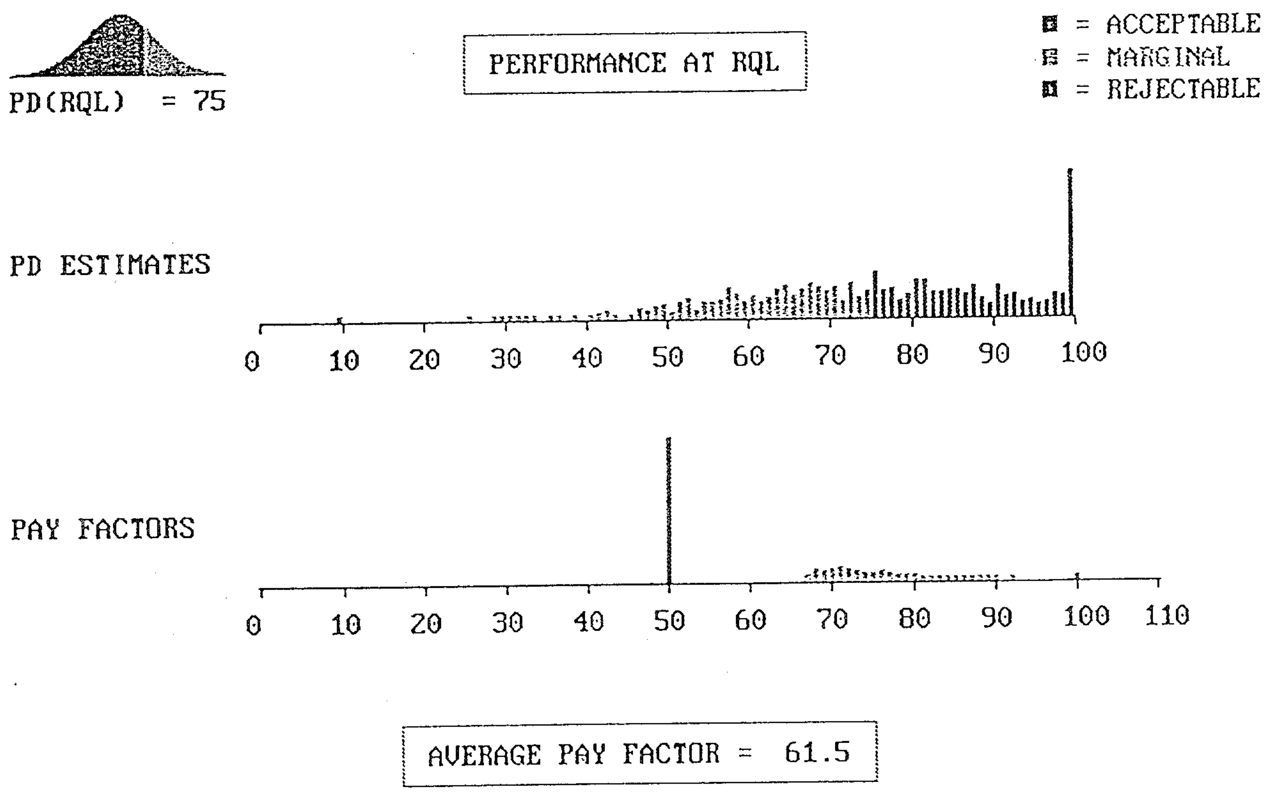


Figure 3.28. Performance at RQL of acceptance procedure developed in Example 3.7.

the AQL and the RQL listed in table 3.7 have been achieved. If these results had not been satisfactory, it would have been necessary to rerun program OCPLOT with different input values until a suitable OC curve was obtained.

As a final check, the program was run again at high precision, producing the results shown in figures 3.29 and 3.30. Figure 3.29 is a plot of the OC curve and figure 3.30 gives the numerical values on the curve. The values in figure 3.30 are in close agreement with the comparable values obtained at intermediate precision in figures 3.27 and 3.28 and confirm that a suitable acceptance procedure has been selected.

Step 10. The final step is to spell out precisely how the acceptance procedure is to be applied. For this example, each lot would be evaluated as follows:

- Take N = 5 samples at random locations.
- Perform the appropriate tests and record the results.
- Compute the mean ($\bar{X}$) and standard deviation (S) of the test results.
- Compute the quality index (Q) for the lower limit (L), the upper limit (U), or both lower and upper limits, as appropriate.

$$\text{LOWER LIMIT: } Q = (\bar{X} - L) / S \qquad (3.11)$$

$$\text{UPPER LIMIT: } Q = (U - \bar{X}) / S \qquad (3.12)$$

- Determine the estimated percent defective (PD) or percent within limits (PWL) for the appropriate limit or limits using tables such as those shown in figures 3.31 and 3.32. An extensive set of tables for a wide range of sample sizes is provided in the appendix.
- Check the RQL provision. If PD $\geq$ 75 (or PWL $\leq$ 25), the highway agency reserves the option to require removal and replacement, corrective action, or the assignment of the minimum pay factor of 50 percent.
- If the lot passes the RQL check, substitute the PD estimate into equation 3.9 (or the PWL estimate into equation 3.10) to obtain the pay factor. The equations are repeated here for convenience.

$$PF = 105 - 0.5\ PD \qquad (3.9)$$

$$PF = 55 + 0.5\ PWL \qquad (3.10)$$

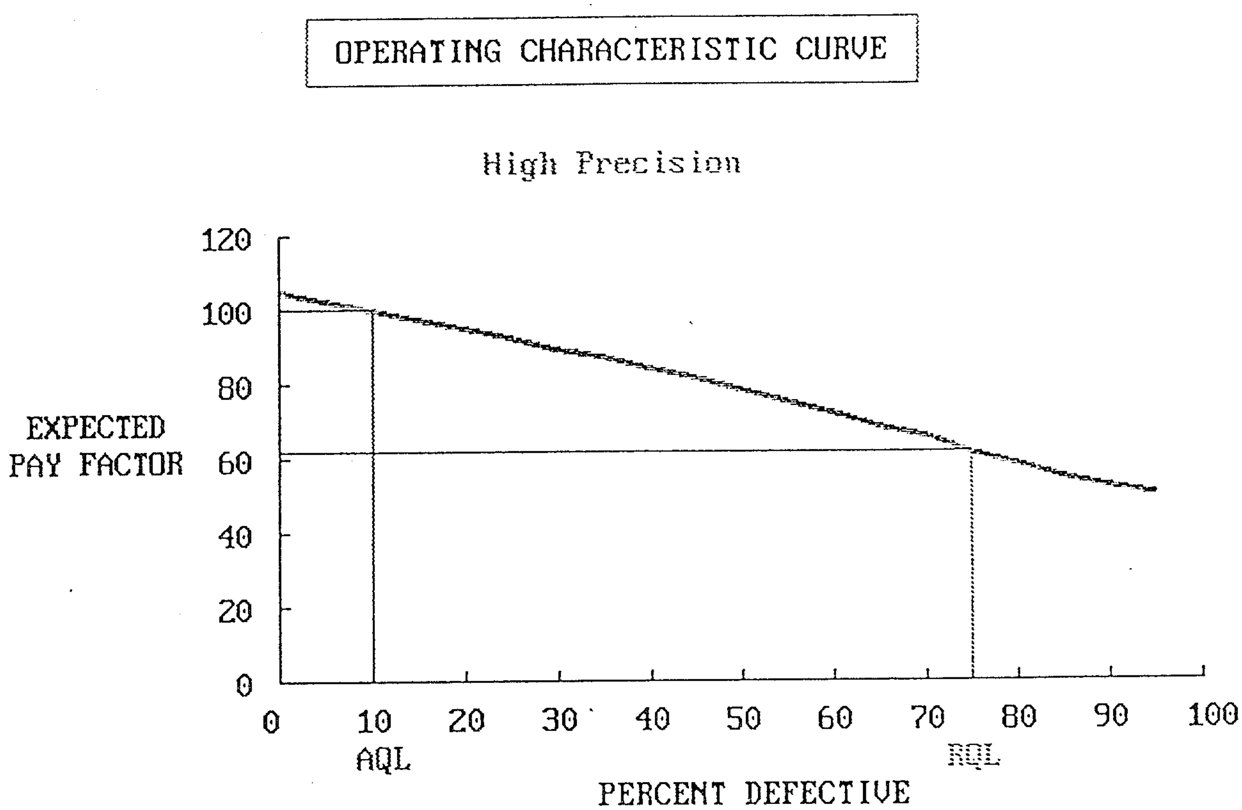


Figure 3.29. OC curve for acceptance procedure developed in Example 3.7.

PERCENT DEFECTIVE		EXPECTED PAY FACTOR
0.0		105.0
5.0		102.5
10.0	———— AQL ————	100.0
15.0		97.6
20.0		95.0
25.0		92.3
30.0		89.6
35.0		87.3
40.0		84.6
45.0		81.8
50.0		78.7
55.0		75.9
60.0		72.5
65.0		69.0
70.0		66.0
75.0	———— RQL ————	61.9
80.0		58.5
85.0		55.1
90.0		52.5
95.0		50.6

Figure 3.30. Numerical values of points on OC curve for acceptance procedure developed in Example 3.7.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 5 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.64	49.29	48.93	48.58	48.22	47.87	47.51	47.15	46.80
0.1	46.44	46.09	45.73	45.38	45.02	44.67	44.31	43.96	43.61	43.25
0.2	42.90	42.54	42.19	41.84	41.48	41.13	40.78	40.43	40.08	39.72
0.3	39.37	39.02	38.67	38.32	37.97	37.62	37.28	36.93	36.58	36.23
0.4	35.88	35.54	35.19	34.85	34.50	34.16	33.81	33.47	33.13	32.78
0.5	32.44	32.10	31.76	31.42	31.08	30.74	30.40	30.06	29.73	29.39
0.6	29.05	28.72	28.39	28.05	27.72	27.39	27.06	26.73	26.40	26.07
0.7	25.74	25.41	25.09	24.76	24.44	24.11	23.79	23.47	23.15	22.83
0.8	22.51	22.19	21.87	21.56	21.24	20.93	20.62	20.31	20.00	19.69
0.9	19.38	19.07	18.77	18.46	18.16	17.86	17.55	17.26	16.96	16.66
1.0	16.36	16.07	15.78	15.48	15.19	14.91	14.62	14.33	14.05	13.76
1.1	13.48	13.20	12.93	12.65	12.37	12.10	11.83	11.56	11.29	11.02
1.2	10.76	10.50	10.23	9.97	9.72	9.46	9.21	8.96	8.71	8.46
1.3	8.21	7.97	7.73	7.49	7.25	7.02	6.79	6.56	6.33	6.10
1.4	5.88	5.66	5.44	5.23	5.02	4.81	4.60	4.39	4.19	3.99
1.5	3.80	3.61	3.42	3.23	3.05	2.87	2.69	2.52	2.35	2.19
1.6	2.03	1.87	1.72	1.57	1.42	1.28	1.15	1.02	0.89	0.77
1.7	0.66	0.55	0.45	0.36	0.27	0.19	0.12	0.06	0.02	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

Figure 3.31. Table for estimation of percent defective (PD) for sample size of N = 5.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 5 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.36	50.71	51.07	51.42	51.78	52.13	52.49	52.85	53.20
0.1	53.56	53.91	54.27	54.62	54.98	55.33	55.69	56.04	56.39	56.75
0.2	57.10	57.46	57.81	58.16	58.52	58.87	59.22	59.57	59.92	60.28
0.3	60.63	60.98	61.33	61.68	62.03	62.38	62.72	63.07	63.42	63.77
0.4	64.12	64.46	64.81	65.15	65.50	65.84	66.19	66.53	66.87	67.22
0.5	67.56	67.90	68.24	68.58	68.92	69.26	69.60	69.94	70.27	70.61
0.6	70.95	71.28	71.61	71.95	72.28	72.61	72.94	73.27	73.60	73.93
0.7	74.26	74.59	74.91	75.24	75.56	75.89	76.21	76.53	76.85	77.17
0.8	77.49	77.81	78.13	78.44	78.76	79.07	79.38	79.69	80.00	80.31
0.9	80.62	80.93	81.23	81.54	81.84	82.14	82.45	82.74	83.04	83.34
1.0	83.64	83.93	84.22	84.52	84.81	85.09	85.38	85.67	85.95	86.24
1.1	86.52	86.80	87.07	87.35	87.63	87.90	88.17	88.44	88.71	88.98
1.2	89.24	89.50	89.77	90.03	90.28	90.54	90.79	91.04	91.29	91.54
1.3	91.79	92.03	92.27	92.51	92.75	92.98	93.21	93.44	93.67	93.90
1.4	94.12	94.34	94.56	94.77	94.98	95.19	95.40	95.61	95.81	96.01
1.5	96.20	96.39	96.58	96.77	96.95	97.13	97.31	97.48	97.65	97.81
1.6	97.97	98.13	98.28	98.43	98.58	98.72	98.85	98.98	99.11	99.23
1.7	99.34	99.45	99.55	99.64	99.73	99.81	99.88	99.94	99.98	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

Figure 3.32. Table for estimation of percent within limits (PWL) for sample size of N = 5.

A summary of these steps is presented in table 3.8. This example has demonstrated the logical sequence of steps to be followed to develop a statistical specification based on either percent defective or percent within limits. The assumptions made and the values selected for this example are typical of many highway applications but are not necessarily appropriate for any specific case. However, by selecting values appropriate for the specification to be developed, and following this same sequence of steps, it should be possible for the user to develop effective and defensible statistical acceptance procedures for a wide variety of construction specifications.

Table 3.8. Summary of specification development steps.

STEP	ACTION
1	Select quality measure (strength, thickness, etc.)
2	Select statistical measure of quality (PD or PWL)
3	Define the AQL in terms of PD or PWL
4	Define the RQL in terms of PD or PWL
5	Determine appropriate average pay factors at AQL and RQL
6	Determine appropriate incentive pay factor (if any)
7	Define lot size
8	Define retest provision (if any)
9	Construct OC curve and make modifications as necessary
10	Describe complete details of acceptance procedure

CHAPTER 4

PROGRAMS CONCHART AND CCDEMO

4.1 THEORY AND USE OF CONTROL CHARTS

A control chart is a statistical procedure used to study and control repetitive processes. A conceptual illustration is shown in figure 4.1 where a continuing sequence of measurements is plotted against either time or order of production. Although each point could represent a single test result, statistical control charts use average values of two or more tests to properly account for within-lot variability. The locations of the lower and upper control limits are dependent upon sample size and process capability and are computed with the aid of special tables. (It is important to note that the control limits usually are not the same as the specification limits imposed by the purchaser.) The normal distributions shown in figure 4.1 represent the production values and the distribution of sample averages that would be expected to occur when the process is in statistical control.

Control charts have been routinely used in the manufacturing industry for more than half a century and, more recently, have proven to be equally useful in many areas of highway construction. Control charts are typically used to monitor the production of highway materials but may also be used to monitor a wide variety of as-built construction characteristics. Although regarded primarily as a process control device designed to aid contractors in meeting specification requirements, control charts can provide useful information to highway agencies, as well. The following are some of the benefits attributed to control charts:

- They establish process capabilities.
- They provide early detection of lack of control.
- They reduce costs associated with rejected work.
- They decrease the level of inspection required.
- They instill a sense of quality awareness.
- They provide documentation of quality achieved.

The two most commonly used measures for control chart applications are the sample mean and range which, when taken together, provide an indication of the average level and variability of the production process. Both the mean chart and the range chart are shown on the same display by program CONCHART.

There are several different decision rules that have been proposed for use with control charts. Program CONCHART allows the user to select either of two commonly used rules as follows:

- Single value outside control limits
- Single value outside control limits or eight values in a row on same side of target line

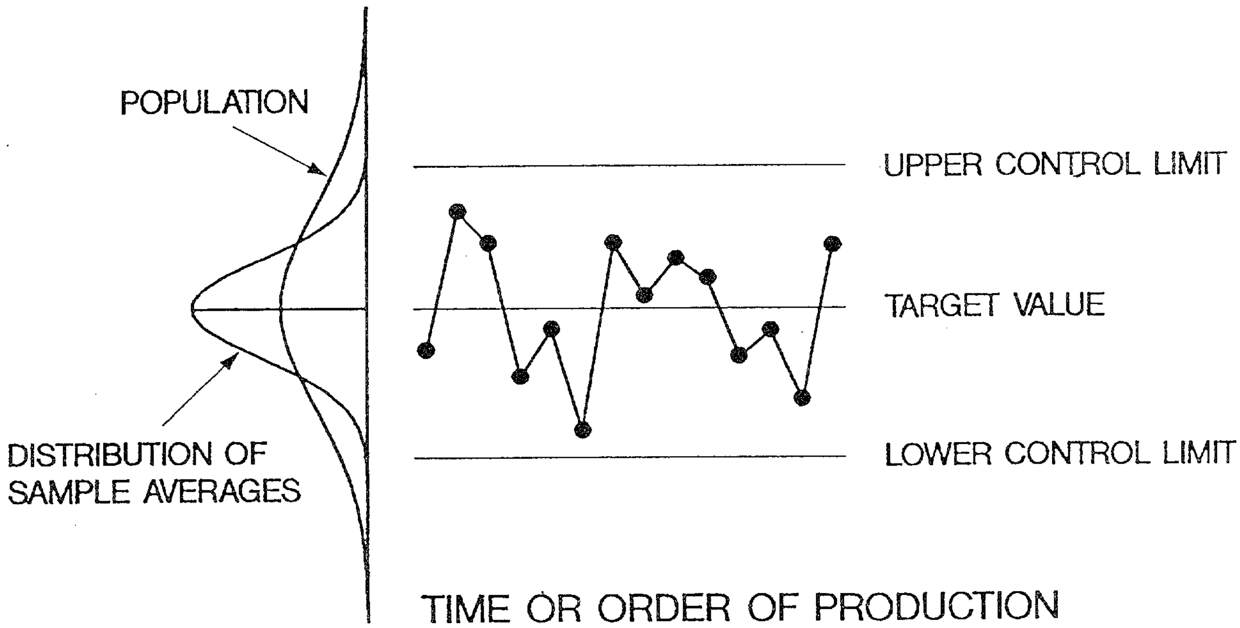


Figure 4.1. Conceptual illustration of control chart.

The decision rules are designed so that there is a relatively small likelihood that production will be interrupted unnecessarily. When either decision rule is triggered, it is likely that a real shift in process conditions has occurred and that an assignable cause should be sought and corrected.

4.2 FEATURES OF PROGRAM CONCHART

Program CONCHART provides two distinctly different modes of operation. It is capable of generating its own random data or reading in the data from an external file. Depending upon which mode is chosen, slightly different menu choices are offered. Figure 4.2 lists some of the options that may be selected from the primary menu.

The capability of generating random data for analysis has been included as an instructional feature and appropriate pauses have been programmed into the output displays to emphasize each step of the operation. These pauses are omitted when the data set is obtained from an external file.

When the selections from the primary menu are complete, the menu will appear similar to those shown in figure 4.3 and figure 4.4, depending upon which data source has been chosen. The prompt "Press any key to continue" at the bottom of the menu display provides a pause that gives the user the opportunity to use the <ESC> key to go back and change some values or press the <PrintScreen> key if a record of the menu selections is desired. Striking almost any other key will cause the program to begin execution, producing a display such as that shown in figure 4.5. (Printouts of any of the graphical displays that follow may be obtained with the <PrintScreen> key, provided the system has graphics capability as discussed in chapter 2.)

The display in figure 4.5 is the result of the entries in the menu shown in figure 4.3. Because the random generation feature is designed to illustrate each step of the control chart process, the first display produces only that portion of the data set from which the control limits are computed. A prompt at the bottom of the screen (not shown in figure 4.5) then instructs the user to "Press any key to plot control limits."

The next display, shown in figure 4.6, plots the target and control lines and the appropriate limiting values computed from the initial group of data points. Another prompt, not shown in the figure, then instructs the user to "Press any key to plot remaining points."

The remaining points, generated under the condition of a drifting mean, are shown in figure 4.7. The single decision rule has been triggered at five locations where the points have fallen above the upper control limit on the mean chart. There are no out-of-control indications on the range chart. A color monitor is useful for this display because different colors have been used to distinguish any points that trigger the decision rules.

DATA SOURCE

- Random Generation
  - PROCESS PARAMETERS .... Enter Mean and Standard Deviation
  - PROCESS CONDITION
    - Steady State
    - Drifting Mean
    - Drifting Standard Deviation
    - Drifting Mean and Standard Deviation
- Data File
  - DATA LOCATION .... Enter Drive: Name: Extension
  - METHOD OF IDENTIFYING STARTING LOT
    - Number
    - Date

TESTS/LOT .... Enter Value

METHOD OF SETTING CONTROL LIMITS

- Computed from Data
- Specified by User .... Enter Predetermined Values

SHOW SPECIFICATION LIMITS

- Yes .... Enter Limit(s)
- No

DECISION RULES

- Single value outside control limits
- Single value out or eight in a row on same side of center

Figure 4.2. Selections available in program CONCHART.

ENTER THE FOLLOWING INFORMATION

DATA SOURCE
Random Generation

PROCESS PARAMETERS
Mean = 6
Standard Deviation = 1.5

PROCESS CONDITION
Drifting Mean

TESTS/LOT
10

CONTROL LOTS
10

SPECIFICATION LIMITS
None

DECISION RULE
Single value outside control limits

Press any key to continue

<ESC> = Back

<END> = Exit

Figure 4.3. Typical completed menu when data set is generated by program CONCHART.

ENTER THE FOLLOWING INFORMATION

DATA SOURCE
Data File

DATA LOCATION
STRENGTH.DAT

STARTING DATE
3-12-94

TESTS/LOT
5

TARGET VALUES
Mean = 5000
Range = 700

MEAN CONTROL LIMITS
Lower = 4600
Upper = 5400

RANGE CONTROL LIMITS
Lower = 0
Upper = 1500

SPECIFICATION LIMITS
Lower = 0
Upper = None

DECISION RULES
Single value outside control limits or eight in a row on same side of center

Press any key to continue

<ESC> = Back

<END> = Exit

Figure 4.4. Typical completed menu when data is read from an external file by program CONCHART.

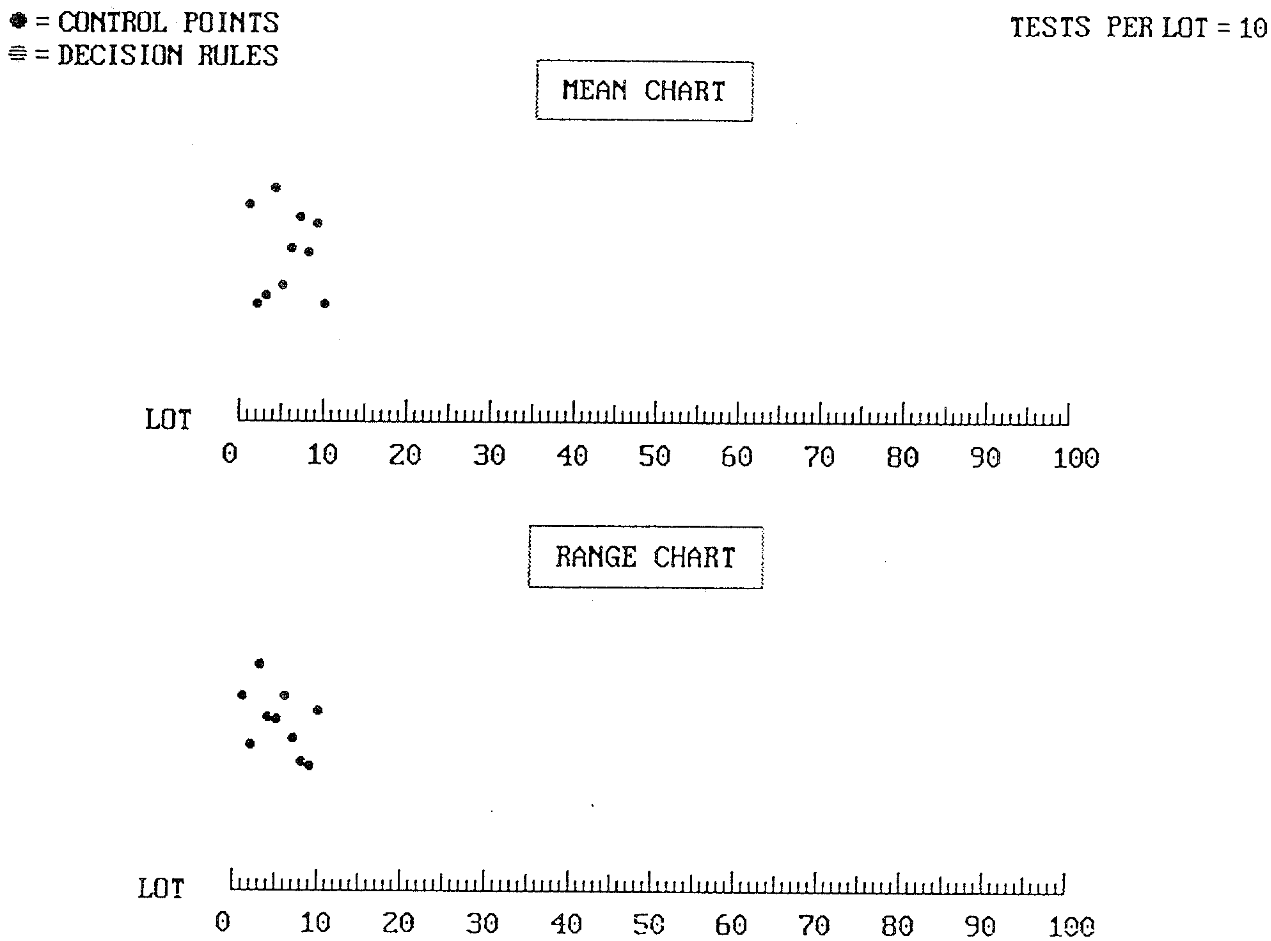


Figure 4.5. First output display showing control points generated by program CONCHART.

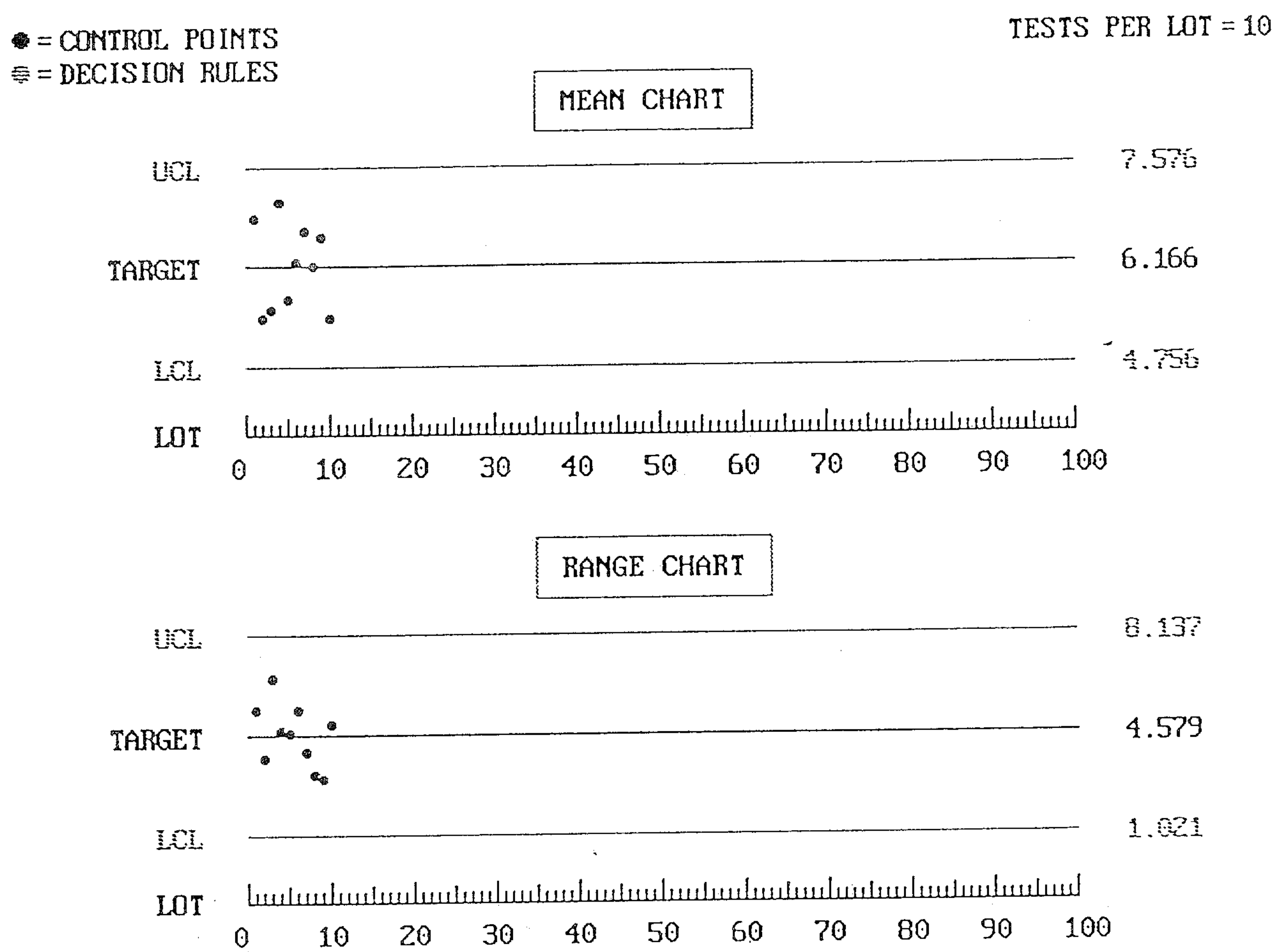


Figure 4.6. Second output display showing control limits computed by program CONCHART.

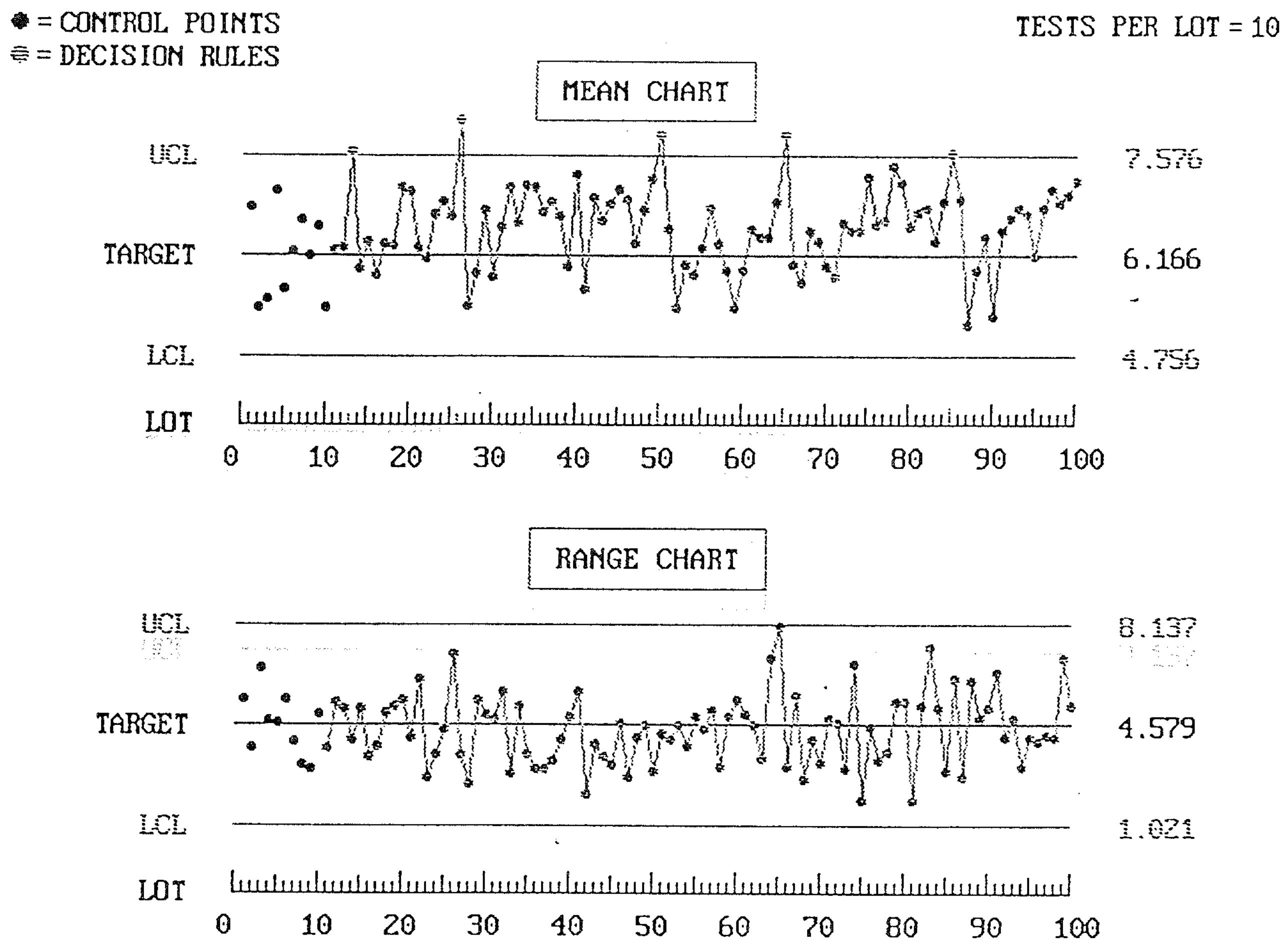


Figure 4.7. Final output display showing completed control charts constructed by program CONCHART.

During the data generation process, whenever a decision rule is triggered, program CONCHART makes an appropriate internal adjustment to bring the process under control. This models in an approximate way the actions that would normally be taken in a production operation.

Following this display, striking a key will produce the upper menu shown in figure 4.8. This menu permits the user to run the program again under the same conditions, enter new input values, or exit. If the program had been run with data obtained from an external file, the lower menu in this figure would have appeared.

4.3 COMPUTATION OF CONTROL CHART LIMITS

Control chart limits are computed from a series of measurements on subgroups of size $N \geq 2$ performed during a period when the process is believed to be under control. It is generally regarded as good practice to use at least 100 individual measurements for this step. Therefore, if the size of each subgroup is N = 5, for example, then at least 100/5 = 20 subgroups should be used to compute the control chart limits. The following expressions apply:

CHART	CENTRAL LINE	CONTROL LIMITS
Mean	$\bar{\bar{X}}$	$\bar{\bar{X}} \pm A_2\bar{R}$
Range	$\bar{R}$	$D_3\bar{R}$ and $D_4\bar{R}$

in which

$\bar{\bar{X}}$ = grand mean of subgroup means

$\bar{R}$ = mean of subgroup ranges

A_2, D_3, D_4 = control chart factors from table 4.1

For either mode of operation, and provided the user has not elected to enter predetermined control limits, program CONCHART uses these expressions with the values in table 4.1 to compute appropriate central lines and control limits. If the number of subgroups specified by the user for this purpose does not make use of at least 100 individual test values, a CAUTION message appears on the screen stating that there may be insufficient information to compute reliable control limits. The user then has the option of proceeding with the current selection or making a new selection.

Data Generation Mode:

SELECT DESIRED OPTION

(1) Run again with same selections
(2) Make new selections and run again
(3) Exit program

SELECTION ■

<ESC> = Back <END> = Exit

Data File Mode:

SELECT DESIRED OPTION

(1) Make new selections and run again
(2) Exit program

SELECTION ■

<ESC> = Back <END> = Exit

Figure 4.8. Ending menus for program CONCHART.

Table 4.1. Control chart factors.

NUMBER OF OBSERVATIONS IN SUBGROUP	A_2	D_3	D_4
2	1.880	0.0	3.267
3	1.023	0.0	2.575
4	0.729	0.0	2.282
5	0.577	0.0	2.115
6	0.483	0.0	2.004
7	0.419	0.076	1.924
8	0.373	0.136	1.864
9	0.337	0.184	1.816
10	0.308	0.223	1.777
11	0.285	0.256	1.744
12	0.266	0.284	1.716
13	0.249	0.308	1.692
14	0.235	0.329	1.671
15	0.223	0.348	1.652

4.4 APPROPRIATE DATA FILE FORMATS

When program CONCHART is used to access data from an external file, the data set must be in either of two formats—space delimited or comma delimited—and must conform to the following field requirements:

FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5 to 19
Lot No. (1 to 4 Digits)	Month (1 or 2 Digits)	Day (1 or 2 Digits)	Year (2 Digits)	Test Data (15 Values)

The lot numbers must be completely numeric with no letters or other characters. Lot numbers need not be a continuous sequence but should be in ascending order. Duplicate lot numbers may not be used but the use of duplicate dates for different lots is permissible.

Module STRENGTH.DAT is a data file created to demonstrate the use of programs CONCHART and CCDEMO. It is in space-delimited format but would work equally well if it had been stored in comma-delimited format. Examples of a few lines of data in both formats are shown below:

Space Delimited

```
LOT DATE   TEST VALUES
 193 10 15 94 5145 4764 5198 4665 5186
 194 10 17 94 4902 4911 4677 4622 5141
 195 10 18 94 5218 5513 4815 4865 5075
```

Comma Delimited

```
LOT DATE   TEST VALUES
 193,10,15,94,5145,4764,5198,4665,5186
 194,10,17,94,4902,4911,4677,4622,5141
 195,10,18,94,5218,5513,4815,4865,5075
```

4.5 DEMONSTRATION PROGRAM CCDEMO

Program CCDEMO is a demonstration version of program CONCHART that runs continuously with no input required from the user. All input selections are randomly generated within the program itself with a short time delay between each step. The completed output display remains on the screen for approximately 10 seconds before the next input sequence begins. Program CCDEMO will continue to run until it is stopped by pressing the <END> key.

4.6 EXAMPLES

Example 4.1 -- Illustration of Process Conditions

The purpose of this example is to illustrate the effect of the four different process conditions that can be selected in the data generation mode. In this mode of operation, the points from which the control chart limits are computed are displayed first (as was shown in figure 4.5) and are not connected by line segments as are the remaining points (figure 4.7). When the remaining points are randomly generated, any tendency to drift is corrected automatically within program CONCHART whenever it is detected by the control chart rule that has been selected.

In order to observe the various types of drift that program CONCHART is capable of producing as part of the random generation process, it is necessary to override the automatic process adjustment feature. This can be accomplished by making the following selections at the appropriate places in the main menu:

DATA SOURCE Random Generation	
PROCESS PARAMETERS Mean = Standard Deviation =	(Use any reasonable values)
PROCESS CONDITION Steady State Drifting Mean Drifting Standard Deviation Drifting Mean and Standard Deviation	(Select desired condition)
TESTS/LOT (Select desired sample size: 2 - 15)	
METHOD OF SETTING CONTROL LIMITS Computed from Data	
NUMBER OF LOTS USED TO COMPUTE CONTROL LIMITS (Enter 99)	

The key entry to override the automatic adjustment feature is the selection of the maximum value of 99 as the number of control lots used to compute control limits. Program CONCHART is capable of displaying 100 points at a time and this causes virtually the entire screen to be filled with control points for which no process adjustments are made. All four process conditions are illustrated in figure 4.9 where it can be seen that the desired types of drift have been achieved.

Example 4.2 -- Control Charts Developed from External Data File

The displays shown in figures 4.5 through 4.7 illustrate the development of control charts and the computation of the control chart limits from data that is randomly generated by program CONCHART. This example demonstrates the construction of control charts from data stored in an external file and illustrates the input sequence when the target values and control limits have been predetermined.

Module STRENGTH.DAT is a file of concrete compressive strength test data that has been created specifically to demonstrate the use of program CONCHART. The data set consists of 200 lots, each with 5 test values, identified by lot numbers 1 through 200 and dates beginning with 1/2/94 and ending with 10/26/94. The data set was randomly generated from a population with a mean of 5000 and a standard deviation of 300.

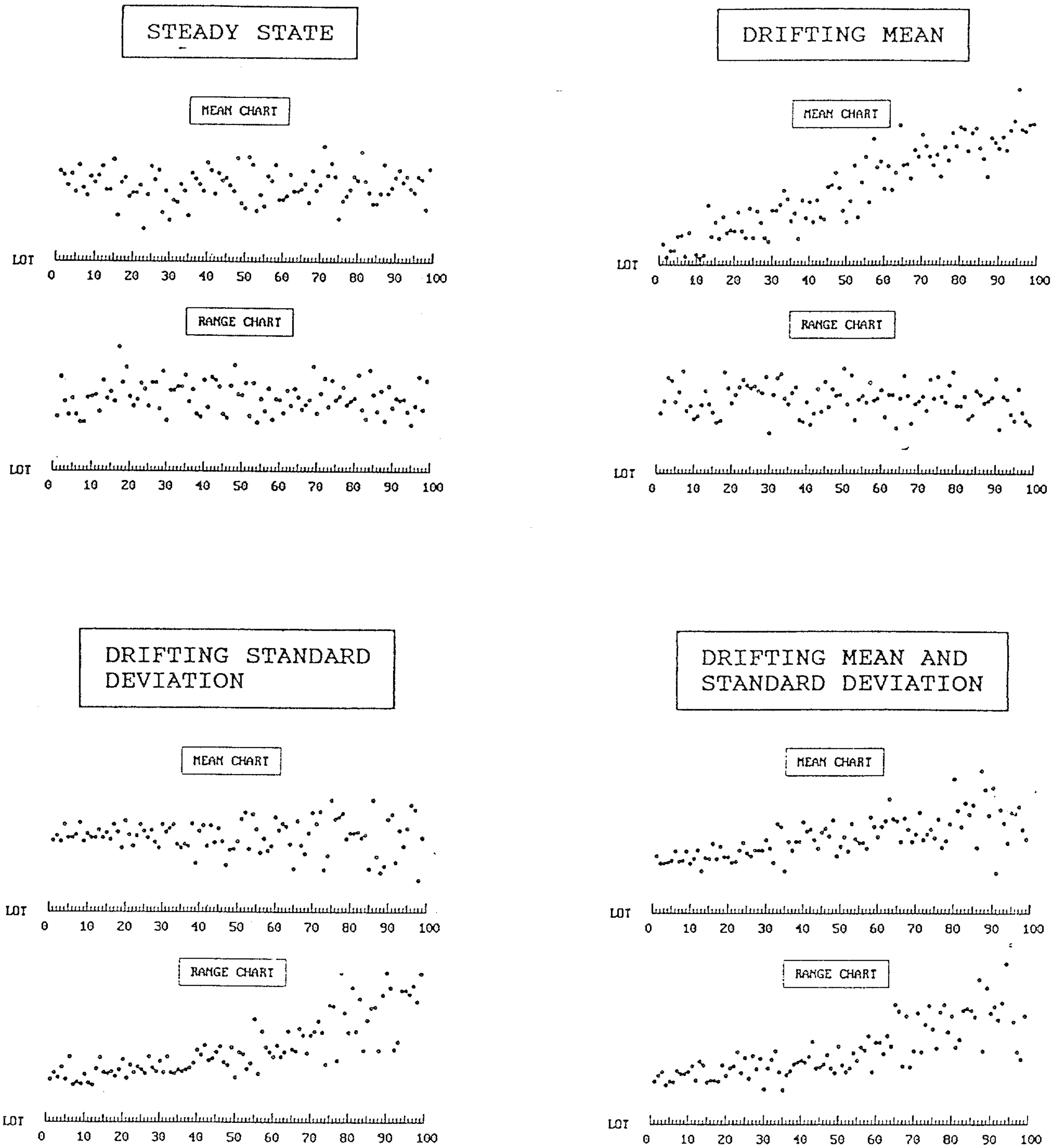


Figure 4.9. Illustration of the four process conditions that can be randomly generated by program CONCHART.

To demonstrate how program CONCHART is used to access an external file, the menu selections shown in figure 4.4 are used. If the file STRENGTH.DAT is located on a drive other than the one from which the program is being run, the drive specification must be included in the menu entry (for example, A:STRENGTH.DAT). The other selections in this menu, not all of which remain in the display of the completed menu, are as follows:

METHOD OF IDENTIFYING STARTING LOT
Date

STARTING DATE

Month	= 3	(1 or 2 Digits)
Day	= 12	(1 or 2 Digits)
Year	= 94	(2 Digits)

TESTS/LOT
5

METHOD OF SETTING CONTROL LIMITS
Specified by User

TARGET VALUES
Mean = 5000
Range = 700

MEAN CONTROL LIMITS
Lower = 4600
Upper = 5400

RANGE CONTROL LIMITS
Lower = 0
Upper = 1500

SHOW SPECIFICATION LIMITS
Yes

SPECIFICATION LIMITS
Lower .... Select "Yes" and enter 4500
Upper .... Select "No"

DECISION RULES
Single value outside control limits or eight in a row on same side of center

At the conclusion of the input sequence, the prompt "Press any key to continue" appears at the bottom of the menu display. Striking almost any key (except <ESC>, <END>, or <PrintScreen>) will commence execution. Because the data file mode is designed for actual applications rather than instruction, the control charts are completed in a single step when this mode of operation is selected.

The output for this example is shown in figure 4.10. Like the data generation mode, lot numbers are plotted on the X-axis and lot 50 corresponds to the selected starting date of 3/12/94. A possible process shift is indicated at three locations. The point for lot 98 on the mean chart is the eighth in a row on the same side of the center line. The point representing lot 108 on the same chart is above the upper control limit. The point at lot 121 on the range chart is the eighth in a row on the same side of the center line. (These are easily seen on a color monitor where any points that trigger decision rules are colored red, as are the corresponding graduation marks on the X-axis of the appropriate control chart.)

If this had been a real application in which actual field data was being monitored at regular intervals, the two potential out-of-control indications on the mean chart would have been of little consequence because they would have indicated small increases in concrete strength. Had the shifts been in the other direction, they would have been of greater concern. The out-of-control indication on the range chart is not especially pronounced, but it might have been of concern because it represents a shift toward greater variability. And, because the nature of concrete strength testing is such that there is often a considerable delay between time of production and time of testing, the earliest possible warning of potential problems can be extremely useful.

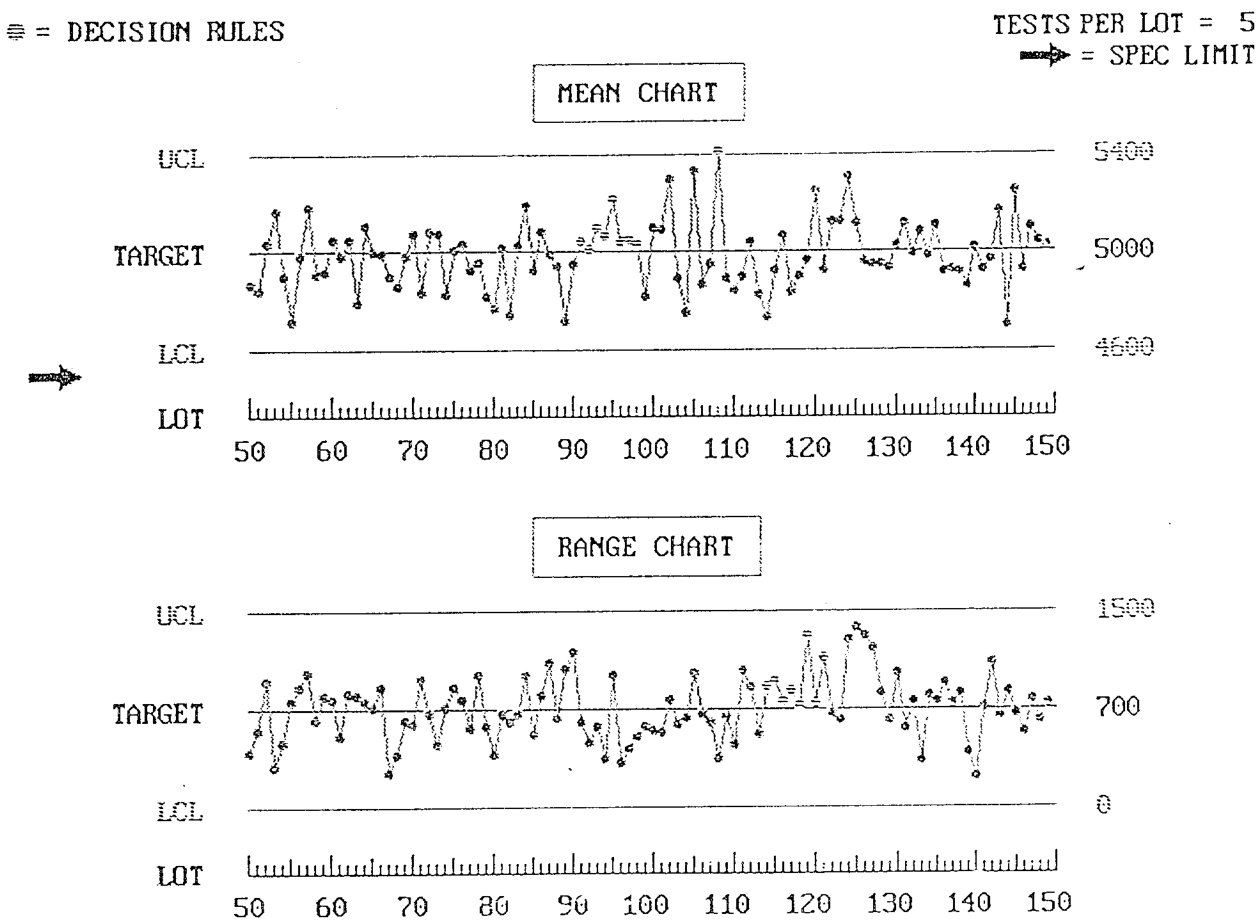


Figure 4.10. Control charts constructed from data stored in external file.

CHAPTER 5

PROGRAM COMPSIM

5.1 COMPUTER SIMULATION

Computer simulation is one of the most powerful analysis methods available for solving a wide variety of complex problems and yet, contrary to what might be expected, it is one of the simplest to understand and apply. Conceptually, most simulations require only the following steps:

- Generate random data simulating the real process
- Apply the procedure that is to be tested
- Store the results in memory

This sequence of steps is then repeated many times—typically 1000, or more—which provides a large data base upon which a variety of analyses may be performed. In this manner, it is possible to accurately assess the performance of the procedure under evaluation.

Computer simulation is particularly useful for problems for which direct, closed-form solutions do not exist or for which very complex mathematics would be required. Many highway acceptance procedures, especially those based on percent defective (PD) or percent within limits (PWL), fall into this category and, in many cases, computer simulation is the only practical means of analysis. Nearly all of the programs described in this manual use computer simulation in one manner or another. This chapter provides additional insight into how computer simulation works and program COMPSIM lets the user experiment with several of these techniques.

5.2 UNIFORM RANDOM NUMBERS

Like most programming languages, Microsoft QuickBASIC provides a uniform random number generator. Whenever it is accessed, it produces a random decimal value between 0.0 and 1.0. These numbers are used primarily to determine random sampling locations but they also play a role in generating normal random numbers, as described in section 5.3.

Within a BASIC program, a uniform random number is obtained by setting a variable equal to RND. For example, when the line of coding X = RND is executed, the variable X takes on the value of a random number between zero and one. When this line of coding is repeatedly executed, a new random number is assigned each time.

With the method just described, identically the same sequence of random numbers will be obtained each time the program is run which is desirable for some comparative studies. For the applications described in this manual, it is more desirable to have each run produce a unique, independent result. This has been accomplished by including the command RANDOMIZE TIMER which keys the random generation process to the computer's internal clock. This causes a unique stream of random numbers to be generated for each run.

Figure 5.1 illustrates the use of uniform random numbers to determine stratified random coring locations for a highway pavement lot. In this figure, a lot is represented as an area 5000 by 10 which, for illustration purposes, may be regarded as being in either metric or English units. A total of 5 cores are to be taken, one from each equal-sized sublot. Figure 5.1 presents the computational procedure which requires 10 uniform random numbers to obtain the 5 coring coordinates. This general procedure is commonly used for a variety of highway sampling applications.

5.3 NORMAL RANDOM NUMBERS

Probably the most common frequency distribution in nature is the normal distribution. Many quantitative measures, including the vast majority of highway construction measurements, conform to a greater or lesser degree to this familiar bell shape. Figure 5.2 shows this distribution with the statistical quality measures PD and PWL illustrated for a double-limit specification.

In order to evaluate the acceptance procedures used in highway construction, it is necessary to have a method to generate random data that is essentially identical to the normally distributed data produced at a construction site. This is accomplished by developing a computer subroutine to generate random numbers from a standard normal distribution having a mean of 0.0 and a standard deviation of 1.0. A simple linear transformation can then be used with these numbers to produce random data having any desired mean and standard deviation and, consequently, any desired quality level in terms of PD or PWL. An example of the BASIC coding to accomplish this is as follows:

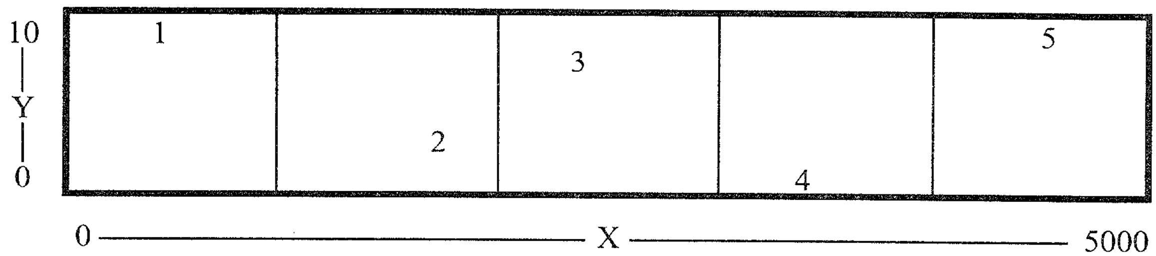
```
X          =     MEAN + STDV * NORM
```

in which

X	=	simulated construction variable
MEAN	=	desired mean value
STDV	=	desired standard deviation
NORM	=	random number from standard normal distribution

Although there are a variety of algorithms available for generating normal random numbers, all require several lines of coding and are sufficiently computationally intensive that they tend to slow the execution of any program using thousands of replications. To develop a faster procedure to avoid this problem, an appropriate algorithm was chosen to create a large file of 5000 scrambled normal numbers. When a normal random number is required, a uniform random number is multiplied by 5000, increased by one, and then truncated to obtain a random integer from 1 to 5000. This is then used to make a random selection from the file of normal numbers.

(NUMERALS 1 - 5 INDICATE APPROXIMATE SAMPLING LOCATIONS)



DETERMINATION OF RANDOM X COORDINATES

SAMPLE NUMBER	RANDOM NUMBER	MULTIPLICATION TERM (SUBLOT LENGTH)	ADDITION TERM (CUMULATIVE LENGTH TO THIS SUBLOT)	X
1	0.603	x 1000	+ 0	= 603
2	0.992	x 1000	+ 1000	= 1992
3	0.086	x 1000	+ 2000	= 2086
4	0.214	x 1000	+ 3000	= 3214
5	0.551	x 1000	+ 4000	= 4551

DETERMINATION OF RANDOM Y COORDINATES

SAMPLE NUMBER	RANDOM NUMBER	MULTIPLICATION TERM (PAVEMENT WIDTH)	Y
1	0.749	x 10	= 7.5
2	0.286	x 10	= 2.9
3	0.562	x 10	= 5.6
4	0.165	x 10	= 1.6
5	0.887	x 10	= 8.9

Figure 5.1. Stratified random sampling procedure applied to highway pavement.

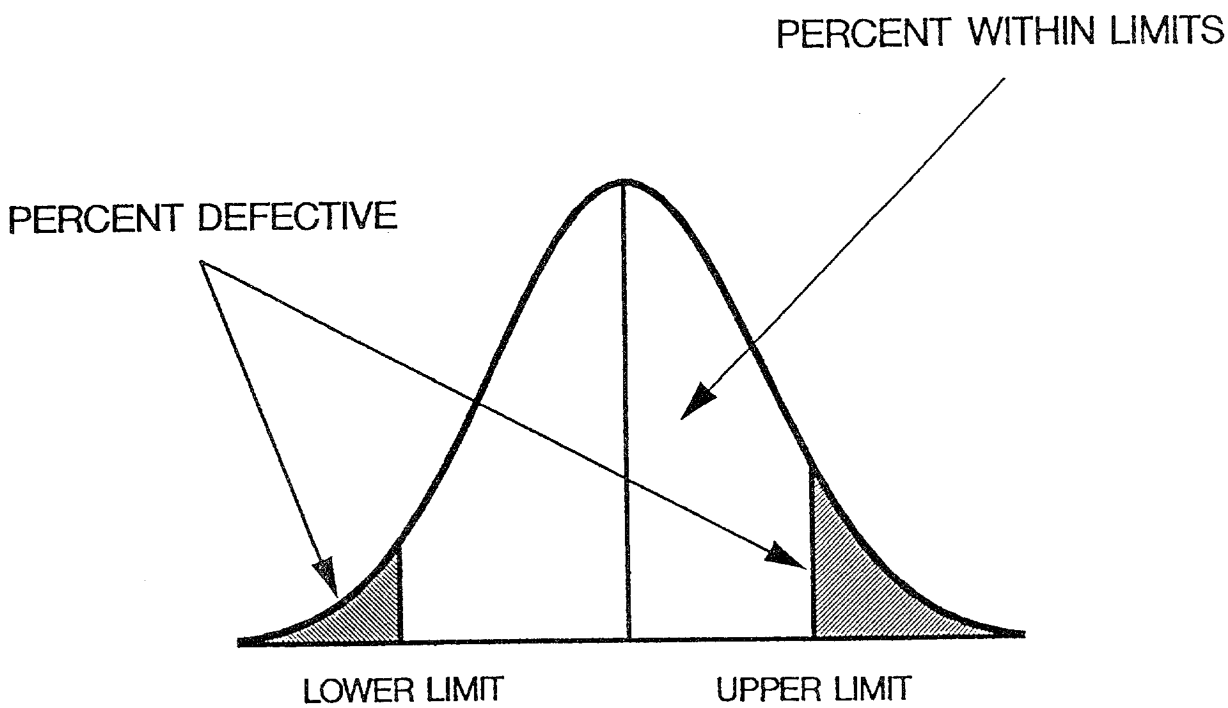


Figure 5.2. Quality measures related to the normal distribution.

5.4 FEATURES OF PROGRAM COMPSIM

Program COMPSIM has been designed to graphically display most of the steps of the simulation process. One option that may be selected from the primary menu is the generation of random data. This is the most fundamental step upon which computer simulation is based and, to provide a better understanding of it, a slight time delay has been incorporated into the program so the user sees the histograms developing one value at a time. This provides a visual impression of how well the shape of the sample set can be expected to conform to the shape of the population as the number of samples increases. When the histogram is complete, the statistical parameters of the sample set are computed and compared to the population parameters to confirm that the random generation process is working properly.

Other options that may be selected allow the user to simulate various levels of quality in terms of PD or PWL using either single-sided or double-sided specification limits. For these selections, only the completed histograms of the simulated data are displayed. The statistical parameters are then calculated and compared to the desired values.

A final option enables the user to observe the detailed computations of a statistical acceptance procedure on a lot-by-lot basis. The procedure may be based on a pass/fail plan or a pay equation. In either case, the calculation of the quality index (Q) to estimate either PD or PWL is shown. Program COMPSIM has been written so the user can interactively repeat this process for as many lots as desired or, at any point, can elect to bypass the detailed computations and go directly to the final summary. As with the other options, histograms are displayed and the statistical parameters are calculated and compared to the desired values to check the performance of the simulation process.

Figure 5.3 shows the opening menu in program COMPSIM that lists the four simulation options that may be selected. The fifth option is to exit the program, which may also be accomplished at any time by striking the <END> key.

5.5 EXAMPLES

PAGE

Example 5.1 -- Generating Normal Random Numbers

When the first option in the opening menu of program COMPSIM is selected, a second menu appears instructing the user to select either a normal or a uniform random distribution to be generated. When a normal distribution is selected, the next menu instructs the user to enter the

SELECT DESIRED OPTION

(1) Random Generation of Data

(2) Simulation of Percent Defective (PD)

(3) Simulation of Percent Within Limits (PWL)

(4) Simulation of Acceptance Procedure

(5) Exit Program

SELECTION ■

<ESC> = Back <END> = Exit

Figure 5.3. Opening menu in Program COMPSIM.

number of random values to be generated and the desired mean and standard deviation. For this example, a total of 1000 samples from a standard normal population (mean of 0.0, standard deviation of 1.0) has been selected.

After the last entry is made, execution begins with a sequence of displays similar to those shown in figure 5.4. For this option, the histogram appears on the screen one value at a time with a short time delay as each new value is randomly generated. This essentially duplicates the manner in which data is obtained from a construction project but at a speed literally thousands of times faster. In order to capture the images shown in figure 5.4, the <Pause> key can be used to temporarily stop the program so that the intermediate stages can be printed with the <PrintScreen> key.

It can be seen in this figure that, while the central tendency is present in the very early stages, the full spread and the true bell shape of the distribution become apparent only after several hundred values have been generated. One conclusion to be drawn from this is that, when evaluating field data for normality, it is not realistic to expect to see a well defined normal distribution until a relatively large amount of data has been collected.

Although the Demonstration Project 89 programs do not provide this capability directly, it was possible to illustrate an important principle by combining portions of programs COMPSIM and CONCHART. The result is shown in figure 5.5 which may be regarded as a companion diagram to figure 5.4. Whereas figure 5.4 demonstrates how the shape of the sample distribution gradually resembles the parent population as the sample becomes larger, figure 5.5 shows the trend of the sample mean and standard deviation throughout this process. In this case, the target values have been set to the appropriate values for a standard normal distribution while lower and upper control values have been selected so that the points plot on a suitable scale. It is readily apparent from this figure that both the mean and the standard deviation of the sample quickly approach the true population values as the sample size increases.

Example 5.2 -- Single-Limit PD Simulation

The second selection from the opening menu in figure 5.3 allows the user to generate a random data set having a specific quality level expressed in terms of percent defective (PD). When this option is selected, a second menu appears instructing the user to enter the type of specification limits (lower, upper, or both). The next menu asks for the limit (or limits) and other basic statistical information about the process.

For this example, a paving operation will be simulated. A single lower limit on paving thickness of 25 cm is specified and 1000 random values will be generated for which the standard deviation is to be 0.5 cm and the quality level is to be 10 percent defective. The purpose of this example is to show that the simulation process is capable of accurately producing the desired results.

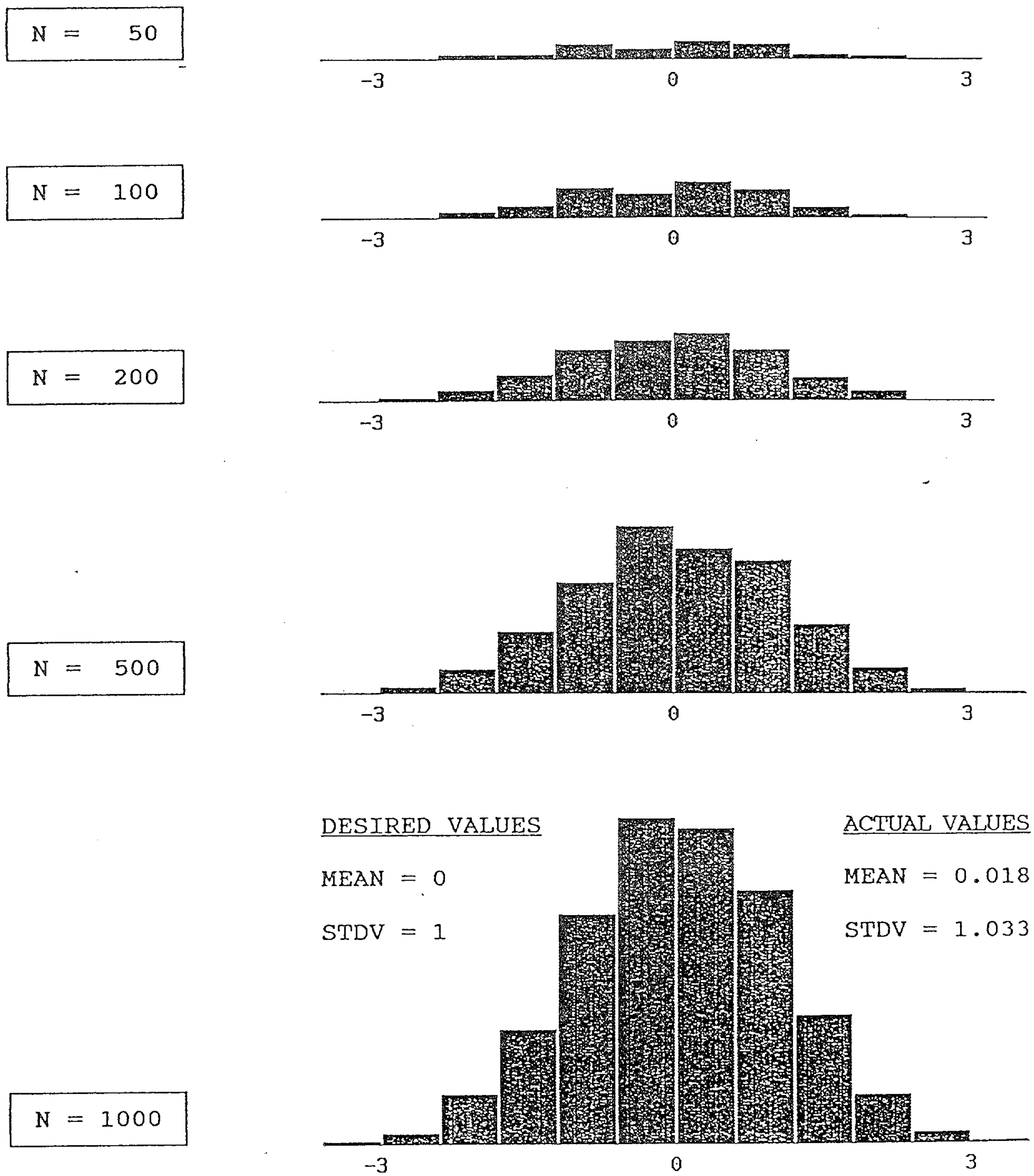


Figure 5.4. Sampling from a standard normal population.

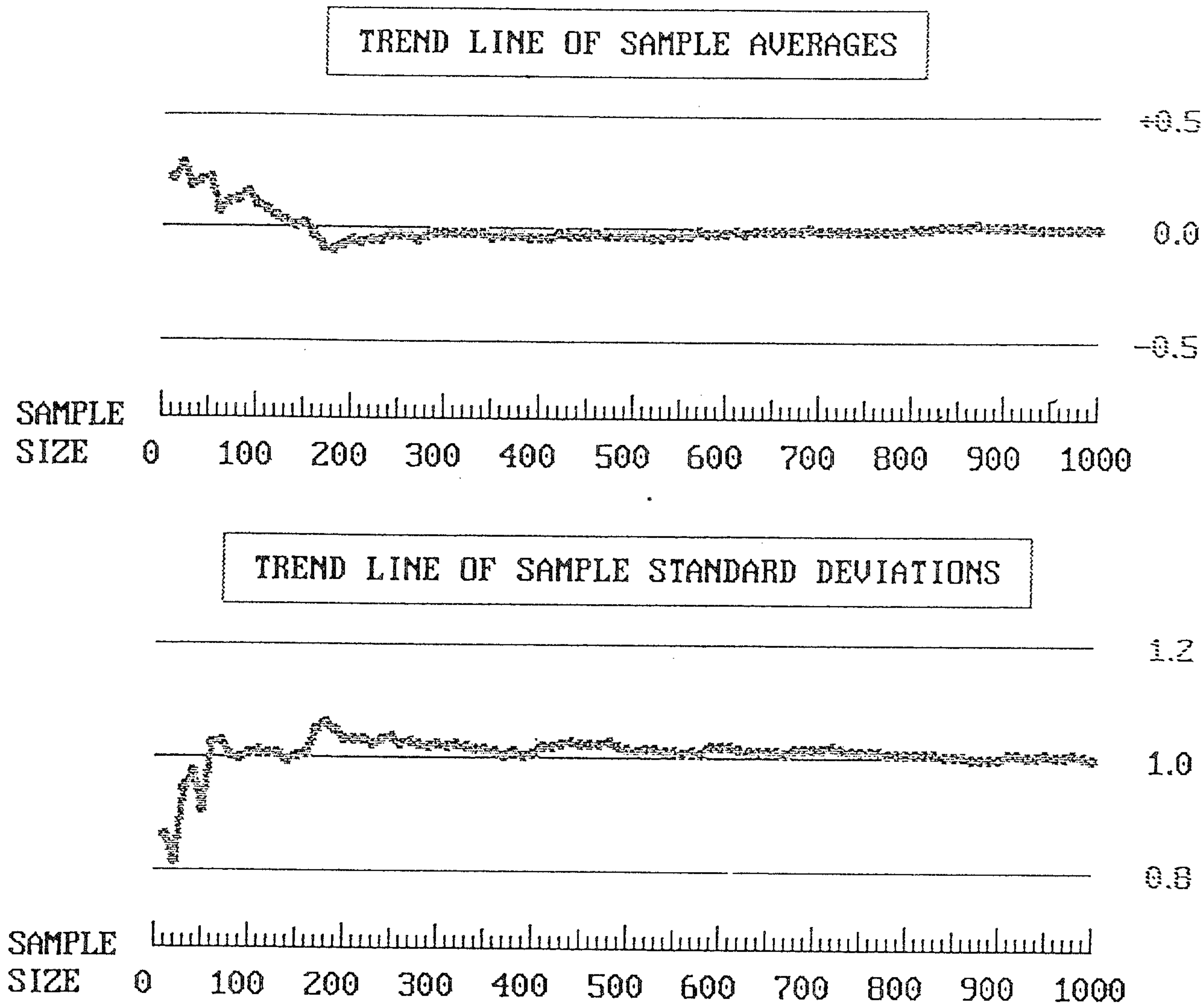


Figure 5.5. Trend lines for mean and standard deviation when sampling from a standard normal population.

Figure 5.6 shows the data distribution that was obtained. Both the desired statistical parameters and the actual values appear in this display. The values printed on the X-axis represent the desired mean and the expected extreme points of the data distribution at plus and minus three standard deviations from the mean. Visually, the data distribution appears to be exactly where it should be and this is confirmed by the statistics displayed in the upper right portion of the screen. The mean, standard deviation, and percent defective are all very close to the desired values. If the purpose of this simulation had been to generate a data set at a specific level of quality for the evaluation of a statistical acceptance procedure, that goal would have been more than adequately accomplished.

Example 5.3 -- Double-Limit PWL Simulation

The third selection from the opening menu in figure 5.3 provides very nearly the same options as the second selection described in example 5.2. The difference is that, for cases in which there is a single lower or upper limit, the quality level to be simulated is expressed in terms of percent within limits (PWL). For double-limit applications, in which there are both lower and upper limits, the desired mean and standard deviation are entered and the resulting PWL value is determined by the simulation process.

This example involves measuring air voids in a bituminous concrete compaction operation. Since performance problems can result when the air voids content is either too low or too high, this will be a double-limit application and the lower and upper limits have been chosen to be 2.0 percent and 8.0 percent, respectively. The purpose of this example is to demonstrate how well a contractor might fare if typical process control is represented by a mean of 6.0 percent and a standard deviation of 1.5 percent.

Figure 5.7 shows the data distribution for this example. The simulation process has produced very nearly the desired mean and standard deviation values. Although very little of the work falls below the lower limit, there is some out-of-specification material above the upper limit. The statistics displayed in the upper right portion of the screen indicate that approximately 90 percent of the work is within limits, a level that is often regarded as acceptable for many construction applications.

A contractor might apply this simulation process to obtain guidance in meeting specification requirements. In this particular example, it would appear that somewhat more compactive effort would be desirable to move the average of the data set closer to the midpoint between the two specification limits. Also, if slightly greater uniformity (smaller standard deviation) could be achieved, this would further improve the contractor's likelihood of doing well under a specification of this type.

Example 5.4 -- Pass/Fail Acceptance Procedure

This example illustrates how program COMPSIM can be used to apply the pass/fail variables procedure of example 3.2 to the simulated compaction operation just discussed in example 5.3. The fourth option in the opening menu is selected to bring up a second menu which allows the user to enter the type of acceptance procedure and other pertinent information. The completed menu is shown in figure 5.8.

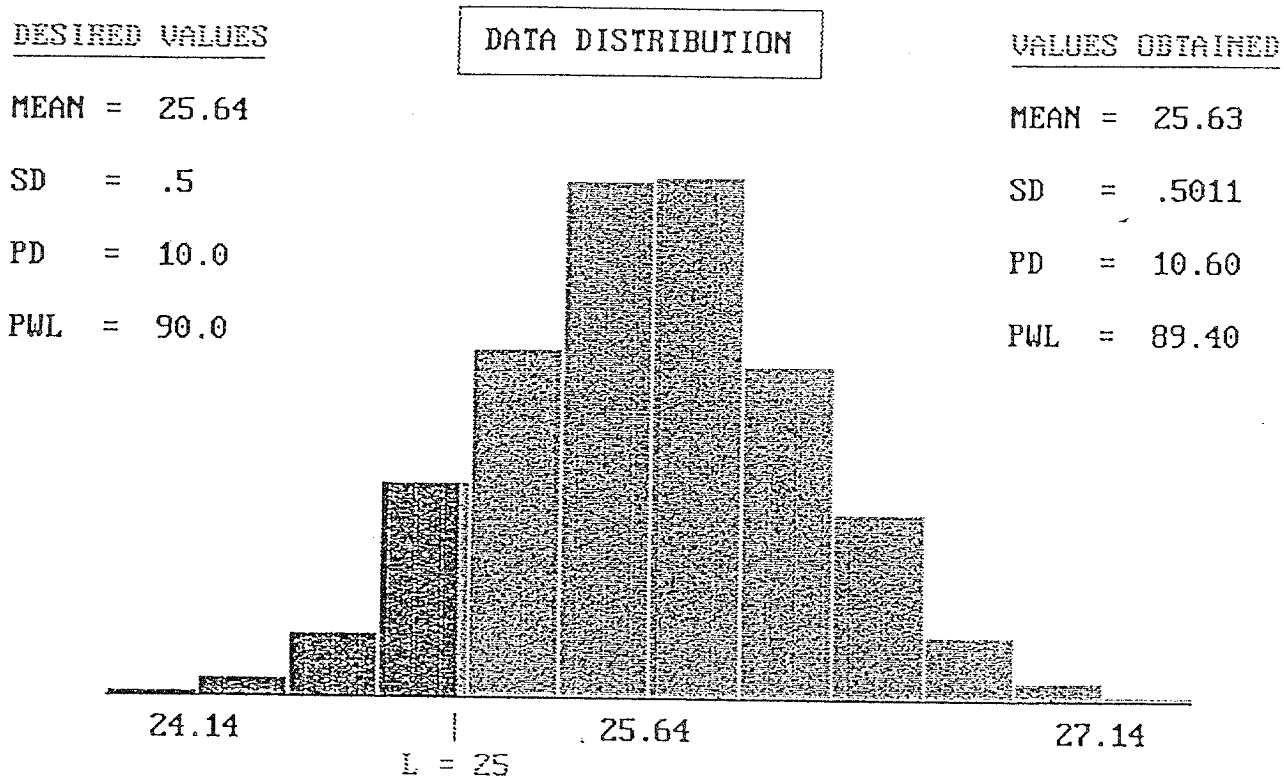


Figure 5.6. Complete data distribution for Example 5.2.

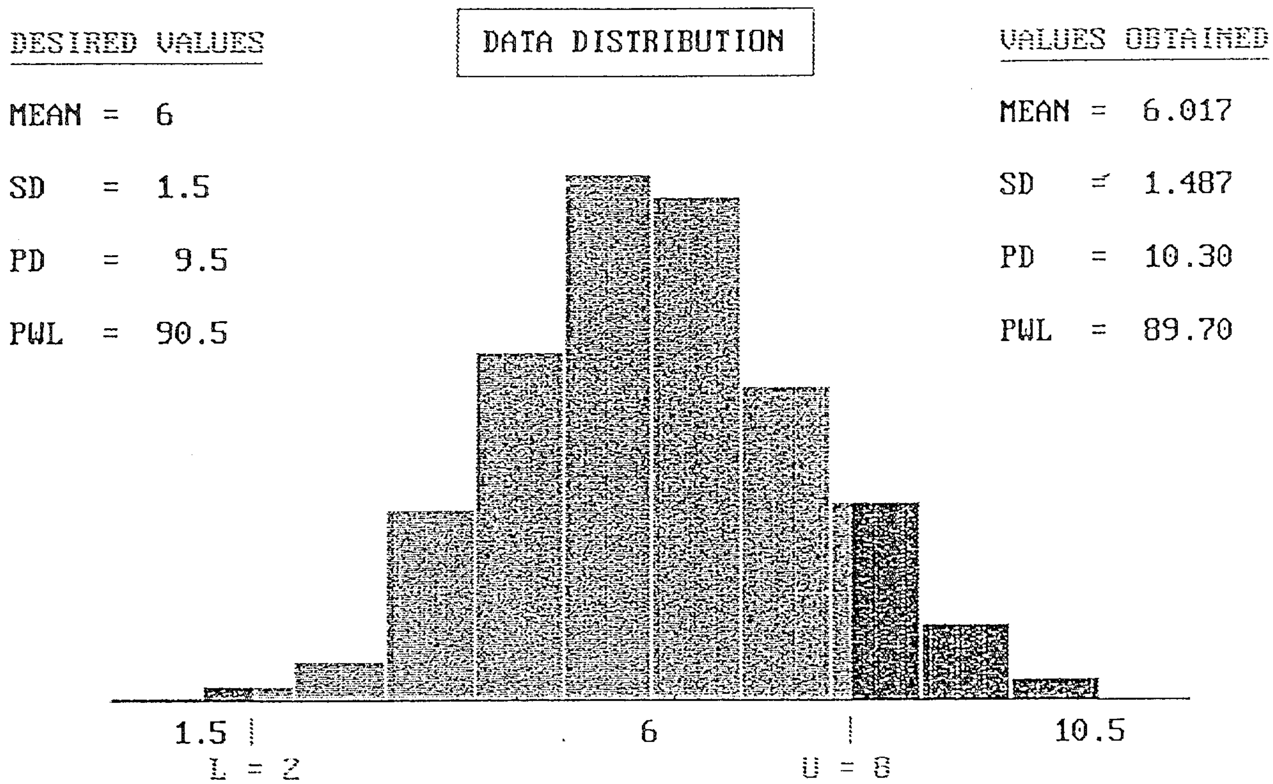


Figure 5.7. Complete data distribution for Example 5.3.

ENTER THE FOLLOWING INFORMATION

TYPE OF PROCEDURE
Pass/Fail

TYPE OF ACCEPTANCE PARAMETER
Percent Defective (PD)

TYPE OF LIMIT(S)
Lower and Upper

LIMIT(S)
L = 2
U = 8

ACCEPTANCE LIMIT

PD = 26

POPULATION PARAMETERS
Mean = 6
Standard Deviation = 1.53

SAMPLE SIZE
8

Press any key to continue

<ESC> = Back <END> = Exit

Figure 5.8. Completed menu for simulation of pass/fail acceptance procedure by program COMPSIM.

Essentially the same entries are used as in example 5.3. To duplicate the acceptance procedure of example 3.2, percent defective (PD) is used as the statistical quality measure and, to be considered acceptable, the estimated percent defective must be less than or equal to PD = 26. It was seen in example 5.3 that a production mean of 6.0 and a standard deviation of 1.5 produced almost exactly 10 percent defective. For this example, the standard deviation has been increased to 1.53 to produce exactly PD = 10 which was the acceptable quality level (AQL) used in example 3.2. Finally, to make this simulation completely consistent with example 3.2, a sample size of N = 8 will be used.

Figure 5.9 shows the data values and statistical computations for the first lot to which this acceptance procedure is applied. The average of the eight test values is not as close to the center of the specification range as might be desired but the standard deviation is sufficiently small that very little material is estimated to be outside specification limits. Using the computed quality index (Q) values, the PD estimates are obtained from tables similar to that shown in figure 3.31 which are obtained from support module TABLEPD.FIL. The total estimated PD of 1.51 is well below the acceptance limit of PD = 26 and, accordingly, the lot is judged acceptable.

Figure 5.10 shows the data values and calculations for a lot that happens to be of poorer quality. Not only is the sample mean of 6.675 too close to the upper limit of U = 8.0, the sample standard deviation of 2.296 is undesirably large. In this case, the total estimated percent defective of 29.41 fails the acceptance requirement of PD $\leq$ 26 and the lot is judged rejectable.

Figure 5.11 shows the histogram of the complete data distribution for this simulation run. The distribution is clearly normal and the mean, standard deviation, and quality level are all very close to the desired values. A tally of passing and failing lots has been kept throughout the simulation process in order to compute the overall probability of acceptance of 0.944 at this quality level. It can be seen that this result compares favorably with the value of 0.951 shown in figure 3.14 for example 3.2.

As a matter of programming convenience, the actual PD and PWL values displayed in figure 5.11 are obtained by actual count of the individual data values. This is believed to be appropriate because these values can be determined directly from the simulation process and do not need to be estimated. If the conventional estimation procedure using the Q statistic were used, slightly different PD and PWL estimates would be obtained.

As a general rule, program COMPSIM and program OCPLOT will produce very nearly the same values when identically the same acceptance procedure is evaluated. However, in order to speed up the execution time of program COMPSIM, it operates at a level of precision comparable to the low precision level of program OCPLOT. Therefore, program COMPSIM should be regarded only as an instructional tool and any actual analyses of acceptance procedures should be performed with program OCPLOT.

LOT 1

TEST VALUES

6.153
6.112
5.834
3.812
6.267
7.765
6.198
5.122

PASS/FAIL COMPUTATION

L = 2   U = 8

Q(L) = ($\bar{X}$ − L)/S = 3.49
ESTIMATED PD(L) = 0.00

Q(U) = (U − $\bar{X}$)/S = 1.87
ESTIMATED PD(U) = 1.51

TOTAL PD = 1.51

PD LIMIT = 26

LOT STATISTICS

N = 8

$\bar{X}$ = 5.908

S = 1.12

***** LOT PASSES *****

DESIRED OPTION?
(1) Display Next Lot
(2) Bypass to Summary

Figure 5.9. Data values and statistical computations for a lot that passes the acceptance procedure of Example 5.4.

LOT 4

TEST VALUES

4.622
3.859
9.983
6.016
8.613
4.364
8.645
7.298

LOT STATISTICS

N = 8

$\bar{X}$ = 6.675

S = 2.296

PASS/FAIL COMPUTATION

L = 2 U = 8

Q(L) = ($\bar{X}$ - L)/S = 2.04
ESTIMATED PD(L) = 0.59

Q(U) = (U - $\bar{X}$)/S = 0.58
ESTIMATED PD(U) = 28.82

TOTAL PD = 29.41

PD LIMIT = 26

***** LOT FAILS *****

DESIRED OPTION?
(1) Display Next Lot
(2) Bypass to Summary

Figure 5.10. Data values and statistical computations for a lot that fails the acceptance procedure of Example 5.4.

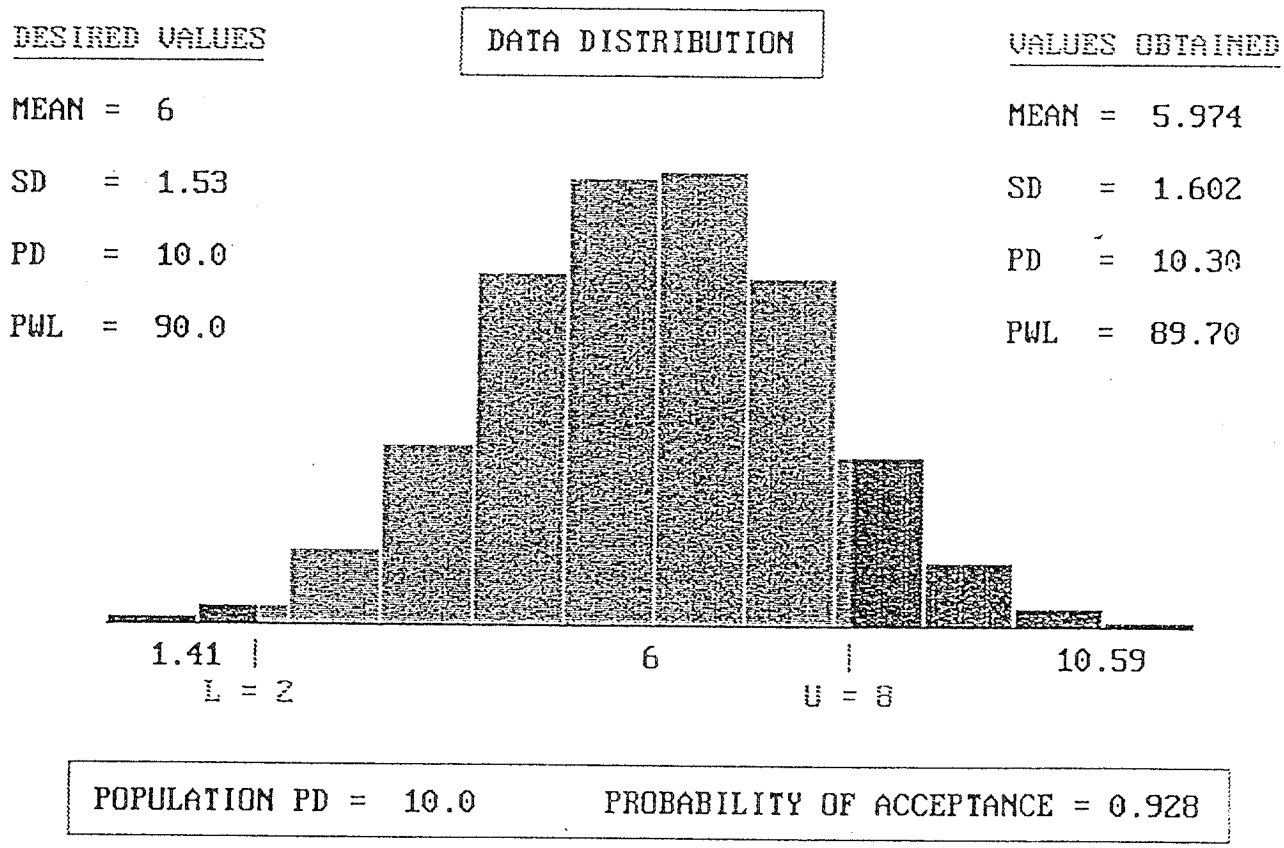


Figure 5.11. Complete data distribution for simulation of pass/fail acceptance procedure of Example 5.4.

Example 5.5 -- Pay Adjustment Acceptance Procedure

The selection of the fourth option from the opening menu in program COMPSIM also provides the capability of analyzing the performance of a pay adjustment acceptance procedure at a specific quality level. In order to relate this example to an earlier example using program OCPLOT, the menu selections shown in figure 5.12 were chosen to provide a direct comparison with example 3.3.

The pay schedule used in example 3.3 is presented here as equation 5.1. It was selected to demonstrate the fact that pay schedules based on either percent defective (PD) or percent within limits (PWL) require an incentive pay provision in order to fairly award an average pay factor of 100 percent at the acceptable quality level (AQL). For this example, it will be assumed that equation 5.1 applies to the paving thickness specification described in example 5.2 for which a single lower limit of 25 cm is used. It was seen in example 5.2 that a production mean of 25.64 cm and a process standard deviation of 0.5 cm produce a quality level of exactly PD = 10 percent (and a corresponding level of PWL = 90 percent) which will be taken as the AQL for this example. Since there is to be no incentive pay provision, the maximum pay factor has been set at PF = 100 in the menu in figure 5.12. Although the sample size is not critical for this demonstration, the same sample size of N = 5 will be used that was used in example 3.3.

$$PF = 10 + PWL_{COMP} \qquad (5.1)$$

in which

PF	=	pay factor (percent)
PWL_{COMP}	=	PWL computed from test values

Figure 5.13 shows the data values and statistical computations for the first lot to which this pay equation is applied. Either the average of 25.59 for the five test values would have to be somewhat larger, or the standard deviation of 0.6363 would have to be somewhat smaller, in order for this lot to be considered completely acceptable. As a result, the quality level is determined to be PWL = 81.54 which is below the AQL of PWL = 90, warranting a pay reduction. The pay factor assigned to the lot by equation 5.1 is PF = 91.54 percent.

Figure 5.14 has been included to illustrate an outcome that will occasionally occur with acceptance procedures of this type. It is seen in this figure that, although none of the individual test values falls below the limit of L = 25, the sample mean and standard deviation are such that the estimated percent within limits is below the acceptance limit of PWL = 90. Provided that no fundamental assumptions such as a normal population or random sampling have been violated, this is a theoretically correct result. The proper interpretation is that, based on the mean and standard deviation estimated from the sample, the amount of the population within specification limits is not as large as desired.

ENTER THE FOLLOWING INFORMATION

TYPE OF PROCEDURE
Pay Adjustment

TYPE OF ACCEPTANCE PARAMETER
Percent Within Limits

TYPE OF LIMIT(S)
Lower

LIMIT(S)
L = 25

PAY EQUATION
PF = 10 + 1.00 PWL

MAXIMUM PAY FACTOR
PF = 100

RQL PROVISION
None

POPULATION PARAMETERS
Mean = 25.64
Standard Deviation = 0.5

SAMPLE SIZE
5

Press any key to continue

<ESC> = Back <END> = Exit

Figure 5.12. Completed menu for simulation of pay adjustment acceptance procedure by program COMPSIM.

LOT 1

TEST VALUES

25.83
26.24
25.16
26.01
24.71

PAY ADJUSTMENT COMPUTATION

L = 25

Q(L) = ($\bar{X}$ - L)/S = 0.93

ESTIMATED PWL = 81.54

* NO RQL PROVISION

PF = 10 + 1.00 PWL = 91.54

LOT STATISTICS

N = 5

$\bar{X}$ = 25.59

S = .6363

DESIRED OPTION?
(1) Display Next Lot
(2) Bypass to Summary

Figure 5.13. Data values and statistical computations for first lot of pay adjustment simulation procedure.

LOT 64

TEST VALUES

26.63
25.46
25.26
25.23
25.76

LOT STATISTICS

N = 5

$\bar{X}$ = 25.67

S = .579

PAY ADJUSTMENT COMPUTATION

L = 25

Q(L) = ($\bar{X}$ - L)/S = 1.16

ESTIMATED PWL = 88.17

* NO RQL PROVISION

PF = 10 + 1.00 PWL = 98.17

DESIRED OPTION?
(1) Display Next Lot
(2) Bypass to Summary

Figure 5.14. Data values and statistical computations for pay reduction lot having no failing test values.

Figure 5.15 illustrates the opposite condition from figure 5.14. Although one of the five test values is below the limit of L = 25, which on an attributes basis might suggest that 1/5 = 20 percent of the population is out of tolerance, the more reliable variables procedure based on the quality index (Q) produces an estimate of PWL = 92.51 within tolerance. This exceeds the AQL of PWL = 90 and, accordingly, there is no pay reduction. If there had been an incentive pay provision, this lot would have received a pay factor somewhat greater than 100 percent.

Figure 5.16 shows the histogram of the complete set of data generated as the result of this simulation run. The distribution is normal and the mean, standard deviation, and quality level are all very close to the desired values. Therefore, the distribution of pay factors computed from this data can be expected to reliably predict the performance of the acceptance procedure at this quality level.

Figure 5.17 presents the histogram of the pay factors computed from the lots represented by the data set in figure 5.16. The individual pay factors range from a maximum of 100 percent down to a minimum of 58.9 percent. It can be seen that this histogram is quite similar to the one shown in figure 3.16 which was obtained under the same conditions by program OCPLOT. The average pay factor of 95.5 percent produced by program COMPSIM in figure 5.17 is in close agreement with the value of 95.3 percent obtained with program OCPLOT in figure 3.16. As noted in example 5.4, programs COMPSIM and OCPLOT will usually produce similar results but, because of its capability for greater precision, program OCPLOT should be used whenever an actual acceptance procedure is to be analyzed.

Figure 5.17 illustrates the performance of this acceptance procedure when the work is consistently at the level of quality that has been defined as acceptable (AQL). This emphasizes once again the point made in chapter 3 that, without some degree of incentive pay provision, acceptance procedures based on PD or PWL are incapable of fairly awarding an average pay factor of 100 percent for AQL work.

An additional example was provided in chapter 3 to demonstrate that this problem can easily be corrected by allowing pay factors in excess of 100 percent for superior quality. This same result can be demonstrated with program COMPSIM. If no maximum pay factor is specified in the menu in figure 5.12, the acceptance procedure will award pay factors greater than 100 percent whenever the quality estimate exceeds the AQL, and the resulting average pay factor at the AQL will then be very close to 100 percent, as desired.

LOT 189

TEST VALUES

25.65
24.84
25.73
25.74
25.55

PAY ADJUSTMENT COMPUTATION

L = 25

Q(L) = ($\bar{X}$ - L)/S = 1.33

ESTIMATED PWL = 92.51

* NO RQL PROVISION

PF = 10 + 1.00 PWL = 100.00

LOT STATISTICS

N = 5

$\bar{X}$ = 25.5

S = .3786

DESIRED OPTION?
(1) Display Next Lot
(2) Bypass to Summary

Figure 5.15. Data values and statistical computations
for full pay lot with one failed test value.

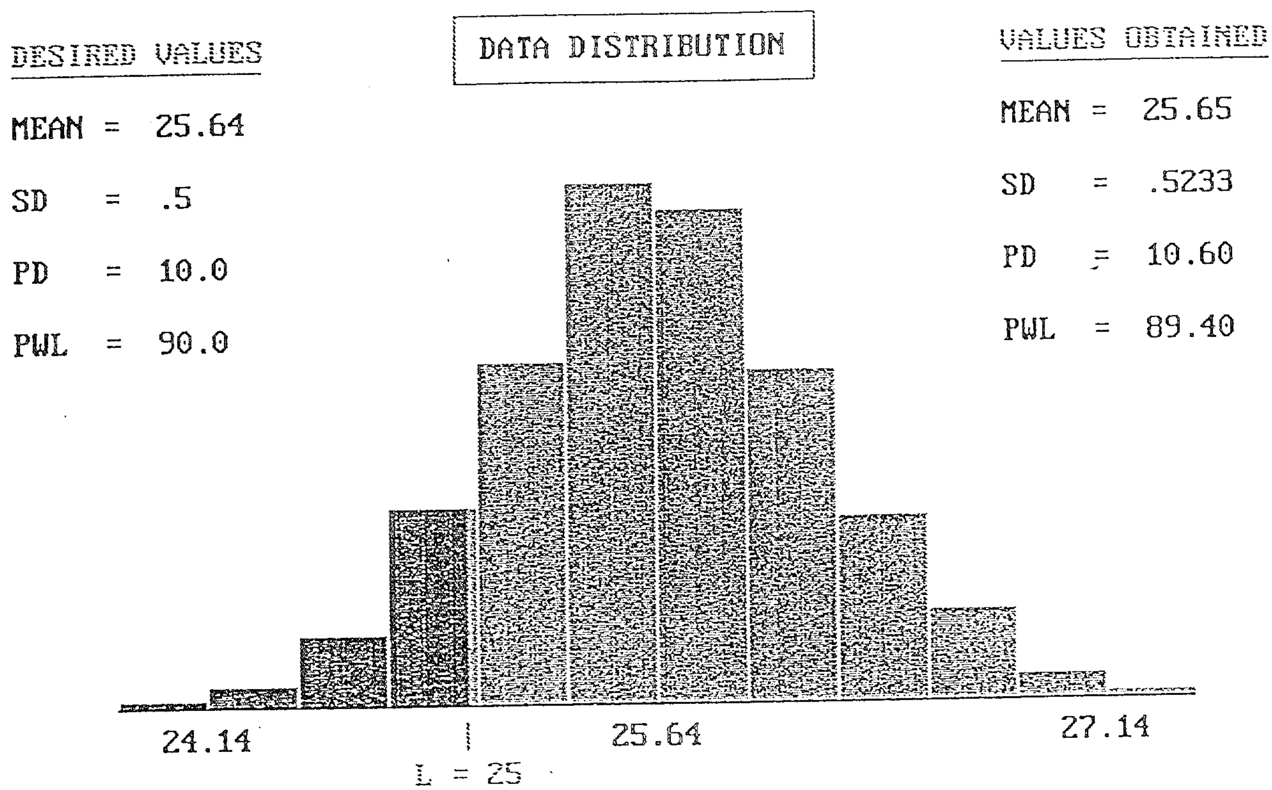


Figure 5.16. Complete data distribution for simulation of pay adjustment acceptance procedure.

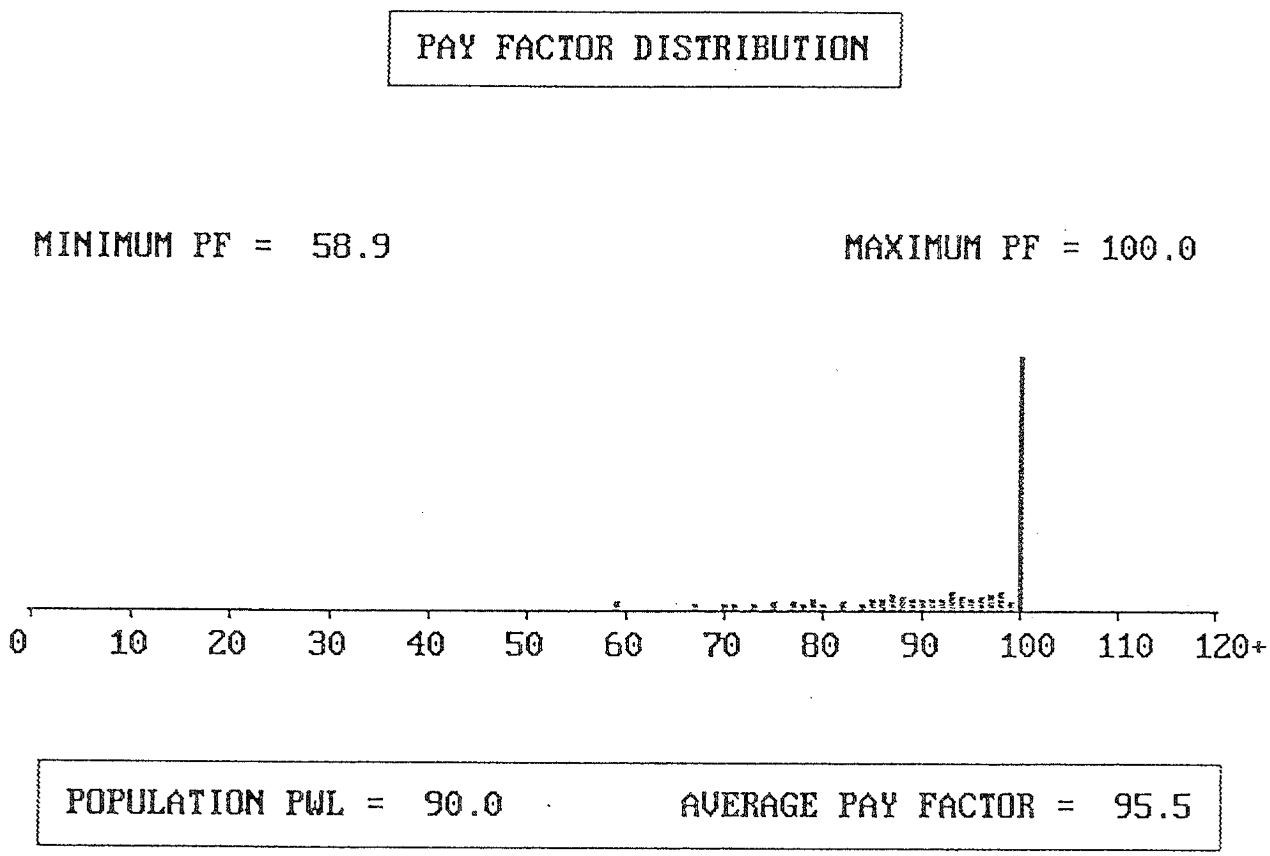


Figure 5.17. Distribution of pay factors produced by simulation of pay adjustment acceptance procedure.

CHAPTER 6

PROGRAM DATATEST

6.1 PURPOSE OF PROGRAM DATATEST

It often is desired to compare two data sets. This might be done to check that production quality has not changed after a temporary shutdown or, conversely, to confirm that a desired change has been achieved. It might also be done to determine the appropriateness of combining two data sets in order to obtain better estimates of the population characteristics.

In statistical jargon, such a comparison is referred to as a hypothesis test. The assumption that there is truly no difference is called the null hypothesis. The appropriate statistics are computed from the data sets and compared to values in standard tables. Whenever a computed value exceeds the table value, the null hypothesis is rejected and the two samples are judged to have come from different populations.

A word of caution is in order. If the two sets of measurements were made with different types of measuring devices (nuclear gauge readings versus core measurements, for example), or if the tests were performed by two operators with markedly different levels of skill, this could produce an apparently significant difference where there truly is none. The user must be alert not to be misled by situations of this type.

When comparing two data sets, the mean and the standard deviation are the two measures that are of particular interest. The standard deviations are compared first, using the F test, because the outcome of this test determines how the test of means is performed. The means are then compared with the t test.

If the purpose of the comparison is to determine whether or not the two data sets represent the same population, then a failure to pass the F test would lead to the conclusion that the populations are different and there would be no need to run the t test. If the purpose is to determine whether or not the two data sets represent the same average level of production, it is necessary to perform the t test to make the final determination. It should be noted that both the F test and the t test in program DATATEST are two-tailed tests and that either an increase or a decrease in the mean or standard deviation may lead to the rejection of the null hypothesis.

Before presenting the details of the tests themselves, it will be useful to discuss what is meant by significant level. This is a statistical term referring to the probability of falsely rejecting the null hypothesis when it really is true. In practical terms, this means erroneously concluding that the population parameters are at different levels when, in fact, they are the same. It is desirable to keep this risk relatively small and, accordingly, program DATATEST allows the user to select from three conventional levels -- 0.01, 0.05, and 0.10. However, the smaller the significance level, the greater the risk of failing to detect a difference when it truly exists. This is illustrated in Example 6.3. The only way to reduce both risks simultaneously is to increase one or both sample sizes.

The opening screens in program DATATEST provide basic operational information that may be stepped through quickly to commence the input sequence. The following queries and responses illustrate a typical session with this program:

```
NUMBER OF VALUES IN DATA SET A?
5

ENTER 5 VALUES FOR DATA SET A
26.2
27.0
25.8
27.9
37.1        (This last value is typed incorrectly.)

CHANGE ANY VALUES? <Y/N>
Y

ENTER COLUMN NUMBER
1

ENTER ROW NUMBER
5

ENTER 5 VALUES FOR DATA SET A
26.2
27.0
25.8
27.9
█           (The incorrect entry is deleted and the cursor is in position for the new entry.)
ENTER 5 VALUES FOR DATA SET A
26.2
27.0
25.8
27.9
27.1        (The correct value has been entered.)

CHANGE ANY VALUES? <Y/N>
N

NUMBER OF VALUES IN DATA SET B?
3
```

ENTER 3 VALUES FOR DATA SET B
25.5
25.8
24.9

CHANGE ANY VALUES? <Y/N>
N

SELECT SIGNIFICANCE LEVEL (ALPHA) TO BE USED FOR F AND T TESTS
(1) 0.01
(2) 0.05
(3) 0.10

A significance level of 0.05 was selected to produce the output shown in figure 6.1. The summary statistics for both data sets are displayed at the top of the screen. The standard deviations are compared and the calculated $F_{CALC} = 3.21$ does not come close to the critical value of $F_{CRIT} = 39.2$ required to conclude (at the 0.05 significance level) that the standard deviations are different. The comparison of the sample means, however, produces a significant result since the calculated value of $t_{CALC} = 2.66$ exceeds the critical value of $t_{CRIT} = 2.45$ at the 0.05 significance level. Therefore, it is concluded that these samples come from different populations. This is highlighted in figure 6.1 by a box drawn around the significant result. In the actual display on the computer monitor, this message flashes.

At this point, the user may strike <ESC> to move back to the previous display, <PrintScreen> to obtain a printout of the results shown in figure 6.1, or <END> to exit the program. Striking any other key gives the user the following options:

(1) SELECT SIGNIFICANCE LEVEL AND RUN AGAIN
(2) CHANGE SOME VALUES IN DATA SET B AND RUN AGAIN
(3) RUN AGAIN WITH NEW DATA
(4) EXIT PROGRAM

6.2 EXAMPLES — PAGE

DATA SET A

N = 5

$\overline{X}$ = 26.8

S = .82158

COMPARE
STANDARD
DEVIATIONS

F(CALC) = 3.21

F(CRIT) = 39.2

NO SIGNIFICANT
DIFFERENCE AT
ALPHA = 0.05

DATA SET B

N = 3

$\overline{X}$ = 25.4

S = .45826

COMPARE
SAMPLE
MEANS

T(CALC) = 2.66

T(CRIT) = 2.45

SIGNIFICANT
DIFFERENCE AT
ALPHA = 0.05

Press any key to continue

Figure 6.1. Typical output display for program DATATEST.

Example 6.1 -- DATATEST Procedure with Similar Standard Deviations

Until the statistical test is actually performed, it usually is not known whether or not the standard deviations computed from the two samples can be regarded as having come from the same population. This example has been constructed to illustrate the case in which they are not found to be statistically significantly different.

For convenience, the two data sets are labeled "Data Set A" and "Data Set B". When they are entered into program DATATEST, it makes no difference which data set is entered first. The only exception would be the case in which it was planned to test the effect of adding or removing certain values from one of the data sets. In this case, the data set to be altered should be entered as "Data Set B" since this is one of the options that may be selected from the final menu.

These data sets might represent test results obtained before and after some process change or they might be data obtained by two different agencies from the same process. In the former case, the statistical test would be performed to judge whether or not a real process shift has occurred. In the latter case, it may be desired to determine if the two data sets are sufficiently similar that they can be pooled to obtain a better estimate of construction quality.

Table 6.1. Data sets for Example 6.1.

DATA SET A				DATA SET B
6.0	5.9	6.2	6.1	6.3
5.7	5.8	6.0	5.9	5.7
5.9	6.0	6.4	6.3	5.5
6.4	5.7	5.9	6.1	6.1
6.2	6.1	6.2	5.8	5.6

DATA SET A		DATA SET B
N = 20	(SAMPLE SIZE)	N = 5
$\bar{X}$ = 6.03	(MEAN)	$\bar{X}$ = 5.84
S = 0.211	(STANDARD DEVIATION)	S = 0.344

The first step is to compare the standard deviations. This is done by computing the F statistic given by equation 6.1.

$$F = S_1^2 / S_2^2 \qquad (6.1)$$

in which

S_1 = the larger of the two standard deviations

S_2 = the smaller of the two standard deviations

In order to judge statistical significance, it is necessary to determine the critical F value which is dependent upon the significance level and the sizes of the two samples. In program DATATEST, this is accomplished with the aid of module FTABLE. (In an actual F table, column and row headings are given in terms of "degrees of freedom" and, for this application, are one less than the sample sizes.) For a significance level of 0.05, and degrees of freedom of 4 and 19 for the numerator and denominator, respectively, the critical F value is $F_{CRIT} = 3.56$. (For this two-tailed test, this value is obtained from an F table for a significance level of $0.05/2 = 0.025$.) Since the calculated value of $F_{CALC} = 0.344^2/0.211^2 = 2.66$ is less than the critical value, the standard deviations are not judged to be significantly different.

When the standard deviations are not found to be significantly different, they may be pooled to obtain a better estimate before proceeding with the comparison of the sample means. This is accomplished in accordance with equation 6.2. For the standard deviation values obtained from the two data sets in table 6.1, the pooled standard deviation is computed to be $S_P = 0.239$.

$$S_P = \sqrt{((N_A - 1)S_A^2 + (N_B - 1)S_B^2) / (N_A + N_B - 2)} \tag{6.2}$$

in which

S_P = pooled standard deviation

N_A = size of sample A

N_B = size of sample B

The sample means can then be compared with the use of the t statistic as indicated in equation 6.3. Like the F statistic, the t statistic is also tabled as a function of degrees of freedom. For this example, the appropriate degrees of freedom (df) is given by equation 6.4, which is the same term that appears in the denominator of equation 6.2. The absolute value symbol in the numerator of equation 6.3 indicates that only a positive value of the t statistic is to be used.

$$t = |X_A - X_B| / S_P\sqrt{1/N_A + 1/N_B} \tag{6.3}$$

for which

$$df = N_A + N_B - 2 \tag{6.4}$$

For a significance level of 0.05 and degrees of freedom of $20 + 5 - 2 = 23$, program DATATEST calls upon support module TTABLE to determine the critical t value to be $t_{CRIT} = 2.07$. Since the value of $t_{CALC} = 1.59$ calculated from equation 6.3 is less than this, the sample means are not judged to be significantly different.

Program DATATEST makes it extremely easy to apply this procedure. The data sets are entered in response to the queries, any necessary changes can be made, the desired significance level is selected, and the output is shown in figure 6.2. For this example, neither the standard

```
DATA SET A                     DATA SET B

  N = 20                         N = 5

  X̄ = 6.03                       X̄ = 5.84

  S = .21051                     S = .34351

COMPARE                        COMPARE
STANDARD                       SAMPLE
DEVIATIONS                     MEANS

F(CALC) = 2.66                 T(CALC) = 1.59

F(CRIT) = 3.56                 T(CRIT) = 2.07

NO SIGNIFICANT                 NO SIGNIFICANT
DIFFERENCE AT                  DIFFERENCE AT
ALPHA = 0.05                   ALPHA = 0.05

     Press any key to continue
```

Figure 6.2. Output display for Example 6.1.

deviations nor the means were found to be statistically significantly different. Therefore, at the level of significance selected for these tests, it is concluded that the two samples come from the same population.

Example 6.2 -- DATATEST Procedure with Unequal Standard Deviations

Program DATATEST is also extremely useful for the more complex case in which the standard deviations cannot be assumed to be equal. For this example, different data sets are used, again labeled "Data Set A" and "Data Set B."

Table 6.2. Data sets for Example 6.2.

DATA SET A				DATA SET B	
26.1	26.5	26.4		25.3	25.2
25.3	25.7	26.9		25.6	25.4
24.9	26.2	25.1		25.1	25.3
26.0	25.9	25.5		24.9	25.7
N = 12		(SAMPLE SIZE)		N = 8	
$\bar{X}$ = 25.87		(MEAN)		$\bar{X}$ = 24.31	
S = 0.584		(STANDARD DEVIATION)		S = 0.259	

As in example 6.1, the first step is to compare the standard deviations using equation 6.1. The calculated F value in this case is $F_{CALC} = 0.599^2/0.259^2 = 5.35$. A nominal significance level of 0.05 will again be used which, for the given sample sizes, produces a critical F value of $F_{CRIT} = 4.71$. Since the calculated value exceeds the critical value, it is judged inappropriate to pool the two standard deviations as was done in the previous example.

Since the standard deviations cannot be pooled, it is necessary to use the t statistic given by equation 6.5 to compare the sample means. What is distinctly different is the manner in which the appropriate degrees of freedom for the t statistic is calculated, as indicated in equation 6.6.

$$t = |X_A - X_B| / \sqrt{S_A^2/N_A + S_B^2/N_B} \qquad (6.5)$$

for which

$$df = (a + b)^2 / (a^2/(N_A + 1) + b^2/(N_B + 1)) - 2 \qquad (6.6)$$

in which $a = S_A^2/N_A$, $b = S_B^2/N_B$, and all other terms are as previously defined.

It should be noted that equation 6.6 is an approximation and that slight variations of it appear in the literature. A brief investigation of three different forms of the equation suggests that they all produce very nearly the same result. The result usually will not be an integer and it is common practice to round it to the nearest integral value before obtaining the critical t value.

Using the values obtained from the two data sets in table 6.2, the calculated t value is found to be $t_{CALC} = 2.87$ with degrees of freedom df = 17. At the significance level of 0.05, this produces a critical t value of $t_{CRIT} = 2.11$. Since $t_{CALC} > t_{CRIT}$, the sample means are judged to be significantly different.

The output display for this example is shown in figure 6.3. In this case, both the sample standard deviations and the sample means are statistically significantly different, suggesting that the data sets come from two distinctly different populations.

Example 6.3 -- Effectiveness of DATATEST Procedure

It was demonstrated in chapter 3 how important it is to construct the operating characteristic (OC) curve to learn how an acceptance procedure will perform. Essentially the same thing must be done to understand both the capabilities and the limitations of the DATATEST procedure at different sample sizes and significance levels.

A separate program, conceptually similar to program OCPLOT, was written to test program DATATEST under a variety of different conditions. The test conditions and typical results are organized in tables 6.3 through 6.6 as follows:

POPULATION STANDARD DEVIATIONS	SAMPLE SIZES EQUAL	UNEQUAL
EQUAL	Table 6.3	Table 6.4
UNEQUAL	Table 6.5	Table 6.6

It is apparent from the results in these tables that both sample size and significance level have an appreciable effect on the ability to correctly detect a true difference. It can be seen in table 6.3 for equal standard deviations and sample sizes that, for sample sizes of $N_A = N_B = 10$ and a significance level of 0.01, the true difference between population means must approach 2.0 standard deviation units before there is a strong likelihood (0.93) that it will be detected. For example, if this were applied to two populations of concrete compressive strength, both having a standard deviation of 2067 kPa (300 psi), then a difference in population means of about 4134 kPa (600 psi) would be required in order for this procedure to have a reasonably good chance of detecting it. If the significance level in this case were increased to 0.05, a true difference of 2.0 standard deviation units would be almost certain to be detected but there would then be a 0.05 chance (approximated as 0.06 in table 6.3) of falsely detecting a difference when there truly is none.

DATA SET A

N = 12

$\overline{X}$ = 25.875

S = .59867

COMPARE
STANDARD
DEVIATIONS

F(CALC) = 5.35

F(CRIT) = 4.71

SIGNIFICANT
DIFFERENCE AT
ALPHA = 0.05

DATA SET B

N = 8

$\overline{X}$ = 25.313

S = .25877

COMPARE
SAMPLE
MEANS

T(CALC) = 2.87

T(CRIT) = 2.11

SIGNIFICANT
DIFFERENCE AT
ALPHA = 0.05

Press any key to continue

Figure 6.3. Output display for Example 6.2.

Table 6.3. Capability of DATATEST procedure with equal sample sizes and equal population standard deviations.

DIFFERENCE IN POPULATION MEANS IN UNITS OF AVERAGE SD	PROBABILITY OF DETECTING DIFFERENCE FOR SELECTED SAMPLE SIZES AND SIGNIFICANCE LEVELS								
	$N_A = 5, N_B = 5$			$N_A = 10, N_B = 10$			$N_A = 15, N_B = 15$		
	0.01	0.05	0.10	0.01	0.05	0.10	0.01	0.05	0.10
0.0	0.01	0.06	0.10	0.01	0.06	0.11	0.01	0.06	0.10
0.5	0.03	0.11	0.19	0.06	0.18	0.28	0.11	0.26	0.38
1.0	0.10	0.30	0.43	0.30	0.56	0.69	0.51	0.76	0.85
1.5	0.24	0.54	0.69	0.68	0.90	0.94	0.89	0.98	0.99
2.0	0.45	0.80	0.89	0.93	0.99	1.00	0.99	1.00	1.00
2.5	0.69	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00

PROBABILITY VALUES OBTAINED BY COMPUTER SIMULATION WITH 1000 REPLICATIONS $SD_A = SD_B$

Table 6.4. Capability of DATATEST procedure with unequal sample sizes and equal population standard deviations.

DIFFERENCE IN POPULATION MEANS IN UNITS OF AVERAGE SD	PROBABILITY OF DETECTING DIFFERENCE FOR SELECTED SAMPLE SIZES AND SIGNIFICANCE LEVELS								
	$N_A = 10, N_B = 5$			$N_A = 20, N_B = 5$			$N_A = 20, N_B = 10$		
	0.01	0.05	0.10	0.01	0.05	0.10	0.01	0.05	0.10
0.0	0.01	0.06	0.10	0.02	0.06	0.11	0.01	0.06	0.10
0.5	0.04	0.15	0.24	0.06	0.16	0.27	0.09	0.24	0.35
1.0	0.19	0.42	0.56	0.25	0.48	0.60	0.46	0.71	0.82
1.5	0.44	0.70	0.80	0.57	0.79	0.87	0.88	0.97	0.98
2.0	0.74	0.91	0.95	0.86	0.95	0.98	0.99	1.00	1.00
2.5	0.91	0.99	1.00	0.98	0.99	1.00	1.00	1.00	1.00

PROBABILITY VALUES OBTAINED BY COMPUTER SIMULATION WITH 1000 REPLICATIONS $SD_A = SD_B$

Table 6.5. Capability of DATATEST procedure with equal sample sizes and unequal population standard deviations.

DIFFERENCE IN POPULATION MEANS IN UNITS OF AVERAGE SD	PROBABILITY OF DETECTING DIFFERENCE FOR SELECTED SAMPLE SIZES AND SIGNIFICANCE LEVELS								
	$N_A = 5, N_B = 5$			$N_A = 10, N_B = 10$			$N_A = 15, N_B = 15$		
	0.01	0.05	0.10	0.01	0.05	0.10	0.01	0.05	0.10
0.0	0.02	0.06	0.10	0.01	0.04	0.09	0.01	0.06	0.11
0.5	0.03	0.11	0.19	0.06	0.18	0.28	0.08	0.25	0.36
1.0	0.12	0.29	0.43	0.26	0.50	0.63	0.44	0.69	0.81
1.5	0.23	0.51	0.66	0.60	0.81	0.88	0.84	0.96	0.98
2.0	0.44	0.72	0.83	0.88	0.98	0.99	0.99	1.00	1.00
2.5	0.63	0.88	0.94	0.98	1.00	1.00	1.00	1.00	1.00

PROBABILITY VALUES OBTAINED BY COMPUTER SIMULATION WITH 1000 REPLICATIONS $SD_A = 2 \times SD_B$

Table 6.6. Capability of DATATEST procedure with unequal sample sizes and unequal population standard deviations.

DIFFERENCE IN POPULATION MEANS IN UNITS OF AVERAGE SD	PROBABILITY OF DETECTING DIFFERENCE FOR SELECTED SAMPLE SIZES AND SIGNIFICANCE LEVELS								
	$N_A = 10, N_B = 5$			$N_A = 20, N_B = 5$			$N_A = 20, N_B = 10$		
	0.01	0.05	0.10	0.01	0.05	0.10	0.01	0.05	0.10
0.0	0.01	0.04	0.08	0.01	0.04	0.08	0.01	0.05	0.09
0.5	0.03	0.10	0.17	0.04	0.14	0.21	0.10	0.26	0.38
1.0	0.13	0.34	0.49	0.24	0.49	0.63	0.46	0.74	0.83
1.5	0.39	0.68	0.82	0.56	0.80	0.89	0.87	0.98	0.99
2.0	0.72	0.90	0.95	0.82	0.96	0.99	1.00	1.00	1.00
2.5	0.90	0.99	1.00	0.96	1.00	1.00	1.00	1.00	1.00

PROBABILITY VALUES OBTAINED BY COMPUTER SIMULATION WITH 1000 REPLICATIONS $SD_A = 2 \times SD_B$

It is interesting to note that when there is truly no difference in population means (0.0 in the first column of tables 6.3 through 6.6), the probability of detecting a significant difference either equals the significance level or is extremely close to it. This is the theoretically expected result and is an indication that the simulation procedure is working properly.

Ultimately, it usually is possible to find a combination of sample sizes and significance level that produces suitably balanced risks. The advantage of tables such as these is that they provide an understanding of the operating characteristics of the procedure and a clear picture of both its capabilities and its limitations. This knowledge should be extremely helpful in ensuring that the DATATEST procedure is applied effectively.

CHAPTER 7

PROGRAM ONETEST

7.1 PURPOSE OF PROGRAM ONETEST

It was seen in chapter 6 that the power of the DATATEST procedure to correctly discern a difference between two populations was strongly dependent upon sample size. It is the purpose of program ONETEST to more dramatically illustrate the weakness of a statistical test based on a single sample.

The objective of the statistical procedure used in this program is to determine whether or not a single quality assurance test performed by the highway agency is consistent with a series of quality control tests performed by the contractor. The statistical parameter used for this illustration is the range, although the principle that is demonstrated applies to any statistical measure. The test requirement is given by equation 7.1 and the appropriate range coefficient (C) is obtained from table 7.1.

$$\overline{X} - C*R \leq X \leq \overline{X} + C*R \qquad (7.1)$$

in which

$\overline{X}$ = average of several quality control tests performed by the contractor

R = range of the quality control tests

C = coefficient by which the range is multiplied

X = single quality assurance test performed by the highway agency

Table 7.1. Range coefficients for ONETEST procedure.

NUMBER OF QC TESTS	RANGE COEFFICIENT (C)
5	1.61
6	1.33
7	1.17
8	1.05
9	0.97
10	0.91

The opening screens in program ONETEST provide basic operational information before the primary screen shown in figure 7.1 appears. The first entries to be made are the sample size for the quality control tests and the range coefficient. Following this, the user selects the statistical parameter to be used to measure the difference between the two populations being compared. Program ONETEST then graphically displays the two normal distributions representing these populations at the appropriate degree of separation as each computation is being performed.

7.2 EXAMPLES

Example 7.1 -- Program ONETEST Applied to Population Means

A sample size of N = 5 quality control tests is used for the first example with the corresponding range coefficient of C = 1.61 obtained from table 7.1. The separation between the two populations is based on the mean values and is expressed in standard deviation units. The appropriate configuration of normal distributions is shown as each of the probability values in the upper right portion of the display is computed. Figure 7.1 shows the completed display with the means of the populations three standard deviations apart.

It is apparent from the results in figure 7.1 that this procedure is very weak in its ability to detect even a large difference in the two populations. In the final configuration shown in this display, the rather large separation of three standard deviation units produces only about a 34 percent chance of detection.

It can also be seen in figure 7.1 that this procedure operates at a significance level of about 0.02 since the risk of falsely detecting a statistically significant difference when there truly is none is 0.02. If a somewhat larger value of this risk could be tolerated, the power of the procedure to detect true differences can be improved. To determine the degree of improvement that might be possible, this run was repeated with a smaller range coefficient. It was found by trial and error that, for a sample size of N = 5, a value of C = 1.17 will raise the significance (risk) level to about 0.05.

The results of this run are shown in figure 7.2. As expected, decreasing the range coefficient has improved the ability of the procedure to detect a true population shift. A difference in population means of three standard deviation units now has a 60 percent chance of being detected, a considerable improvement over the value of 34 percent in figure 7.1. However, this improvement has been obtained at the expense of having a 5 percent chance of falsely detecting a difference when the two populations are truly identical. Whereas this 5 percent risk may be regarded as acceptable for many applications, the corresponding risk of 40 percent of failing to detect a shift as large as three standard deviations almost certainly would not be. As demonstrated with the DATATEST procedure in chapter 6, the only way to improve both risks is to increase the sample sizes.

SINGLE SAMPLE TEST PROCEDURE

$\bar{X} - C*R \leq X \leq \bar{X} + C*R$

$\bar{X}$ = QC DATA AVERAGE
R = RANGE OF QC DATA
C = RANGE COEFFICIENT
X = SINGLE QA ACCEPTANCE TEST

QC SAMPLE SIZE = 5   C = 1.61

DIFFERENCE IN MEANS (SD UNITS)	PROBABILITY OF DETECTING DIFFERENCE
0.0	0.02
0.5	0.03
1.0	0.06
1.5	0.09
2.0	0.16
2.5	0.23
3.0	0.34

POPULATIONS

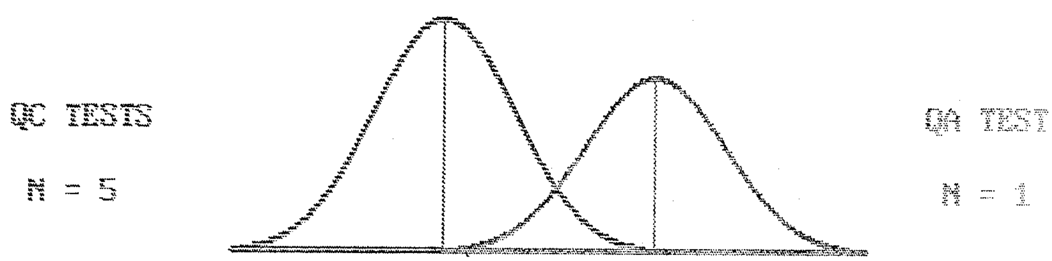


Figure 7.1. Program ONETEST display for Example 7.1.

SINGLE SAMPLE TEST PROCEDURE

$$\bar{X} - C*R \leq X \leq \bar{X} + C*R$$

$\bar{X}$ = QC DATA AVERAGE
R = RANGE OF QC DATA
C = RANGE COEFFICIENT
X = SINGLE QA ACCEPTANCE TEST

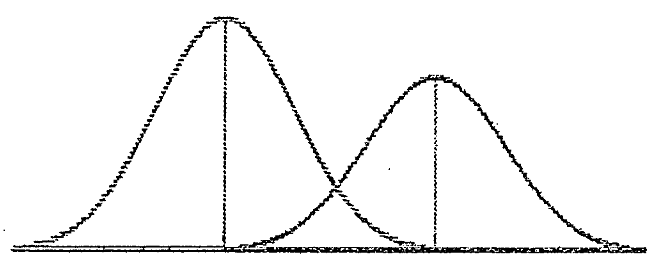
QC SAMPLE SIZE = 5 C = 1.17

DIFFERENCE IN MEANS (SD UNITS)	PROBABILITY OF DETECTING DIFFERENCE
0.0	0.05
0.5	0.07
1.0	0.10
1.5	0.21
2.0	0.31
2.5	0.44
3.0	0.60

POPULATIONS

QC TESTS

N = 5



QA TEST

N = 1

Figure 7.2. Display for modified procedure in Example 7.1.

Example 7.2 -- Program ONETEST Applied to Population PD

This example illustrates the same procedure but with a different sample size and quality measure. A sample size of N = 7 and the corresponding range coefficient of C = 1.17 obtained from table 7.1 are used and the separation of the two populations is expressed in units of percent defective (PD), indicated by the shaded areas under the normal distributions displayed by program ONETEST in figure 7.3. It is apparent from the results shown in this display that this example suffers from the same weaknesses observed in example 7.1.

Example 7.3 -- Program ONETEST Applied to Population PWL

For this final example, the sample size is increased to N = 10 quality control tests and a range coefficient of 0.91 is used. The separation of the two populations is expressed in units of percent within limits, indicated by the shaded areas under the normal distributions in figure 7.4. The results are very similar to the previous examples, demonstrating that this procedure has very little ability under any circumstances to detect appreciable differences between two populations.

SINGLE SAMPLE TEST PROCEDURE

$$\bar{X} - C*R \leq X \leq \bar{X} + C*R$$

$\bar{X}$ = QC DATA AVERAGE
R = RANGE OF QC DATA
C = RANGE COEFFICIENT
X = SINGLE QA ACCEPTANCE TEST

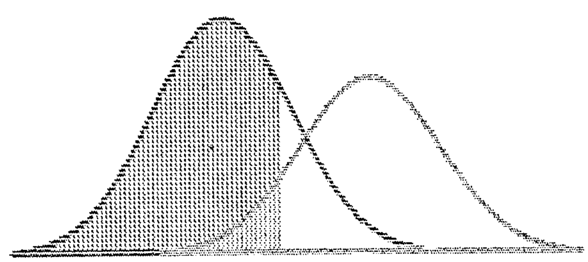
QC SAMPLE SIZE = 7 C = 1.17

DIFFERENCE IN LEVELS OF PD	PROBABILITY OF DETECTING DIFFERENCE
0	0.02
10	0.03
20	0.04
30	0.07
40	0.10
50	0.12
60	0.18
70	0.23

POPULATIONS

QC TESTS

N = 7



QA TEST

N = 1

Figure 7.3. Program ONETEST display for Example 7.2.

SINGLE SAMPLE TEST PROCEDURE

$\bar{X} - C*R \leq X \leq \bar{X} + C*R$

$\bar{X}$ = QC DATA AVERAGE
R = RANGE OF QC DATA
C = RANGE COEFFICIENT
X = SINGLE QA ACCEPTANCE TEST

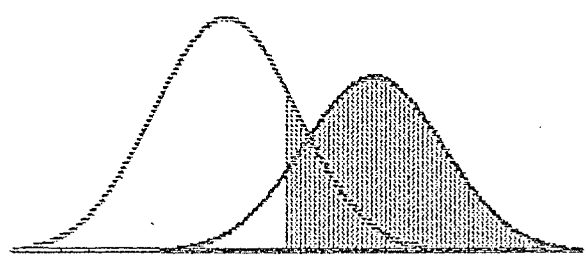
QC SAMPLE SIZE = 10 C = 0.91

DIFFERENCE IN LEVELS OF PWL	PROBABILITY OF DETECTING DIFFERENCE
0	0.02
10	0.04
20	0.06
30	0.08
40	0.11
50	0.16
60	0.23
70	0.29

POPULATIONS

QC TESTS

N = 10



QA TEST

N = 1

Figure 7.4. Program ONETEST display for Example 7.3.

CHAPTER 8

PROGRAM PAVESAMP

8.1 PURPOSE OF PROGRAM PAVESAMP

Program PAVESAMP was developed to demonstrate two important aspects of statistical sampling. It illustrates a commonly used procedure to determine stratified random sampling locations for highway pavement (presented in figure 5.1 in chapter 5), and it demonstrates the tendency for the averages of sample estimates to approach the averages of the true population values as the number of lots increases.

For each run, a simulated length of pavement is displayed with two different colors representing conforming and nonconforming material. The quality level is randomly selected and may range from completely conforming to almost entirely nonconforming. The simulated pavement lot is divided into equal-sized sublots and a single random sample is taken from each. Within the program, two uniform random numbers are generated in order to compute a random X,Y coordinate (station and offset) for each sublot sampling location.

The sampling locations are shown graphically on the pavement display and the sample values appear on the screen as each coordinate is computed. If desired, the sample estimates may be checked by performing computations similar to those outlined in figure 5.13 in chapter 5 and then referring to the percent defective or percent within limits estimation tables in figures 3.31 or 3.32 in chapter 3. (An extensive set of tables is also contained in the appendix.)

At the end of each run, the prompt “Run Again? <Y/N>” appears on the screen. This allows the user to repeat the process as many times as desired by entering <Y>, <y>, or <ESC>. Entering <N> or <n> produces a table summarizing the results of all runs up to that point and offers the user the choice of continuing with additional runs or terminating the session. The <END> key may be used at any time to exit the program.

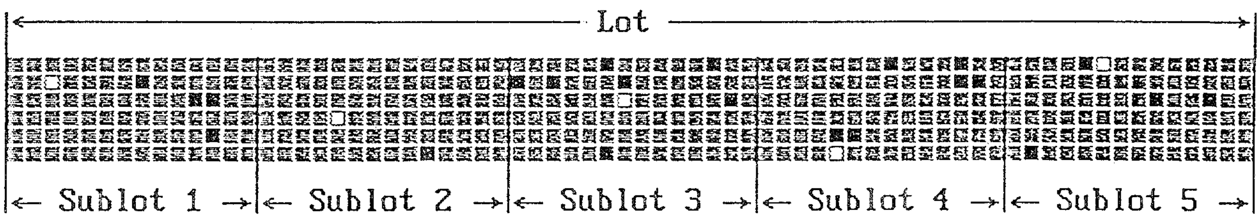
8.2 EXAMPLES

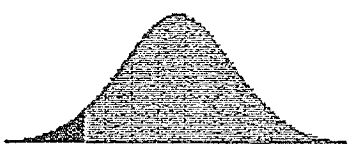
Example 8.1 -- Typical Runs of Program PAVESAMP

Figures 8.1 through 8.4 have been chosen to demonstrate the sampling procedure and statistical estimation process at quality levels ranging from very good to very poor. The true values for

STRATIFIED RANDOM SAMPLING

▩ = CONFORMING ▩ = NONCONFORMING SAMPLE SIZE = 5



POPULATION	SAMPLE
	10.381
	10.630
	10.276
	10.206
LIMIT = 10.0	10.131

	ACTUAL	ESTIMATED
AVG	10.36	10.325
STDV	0.22	0.194
PD	5.24	1.02
PWL	94.76	98.98

Figure 8.1. Program PAVESAMP display depicting pavement of very high quality.

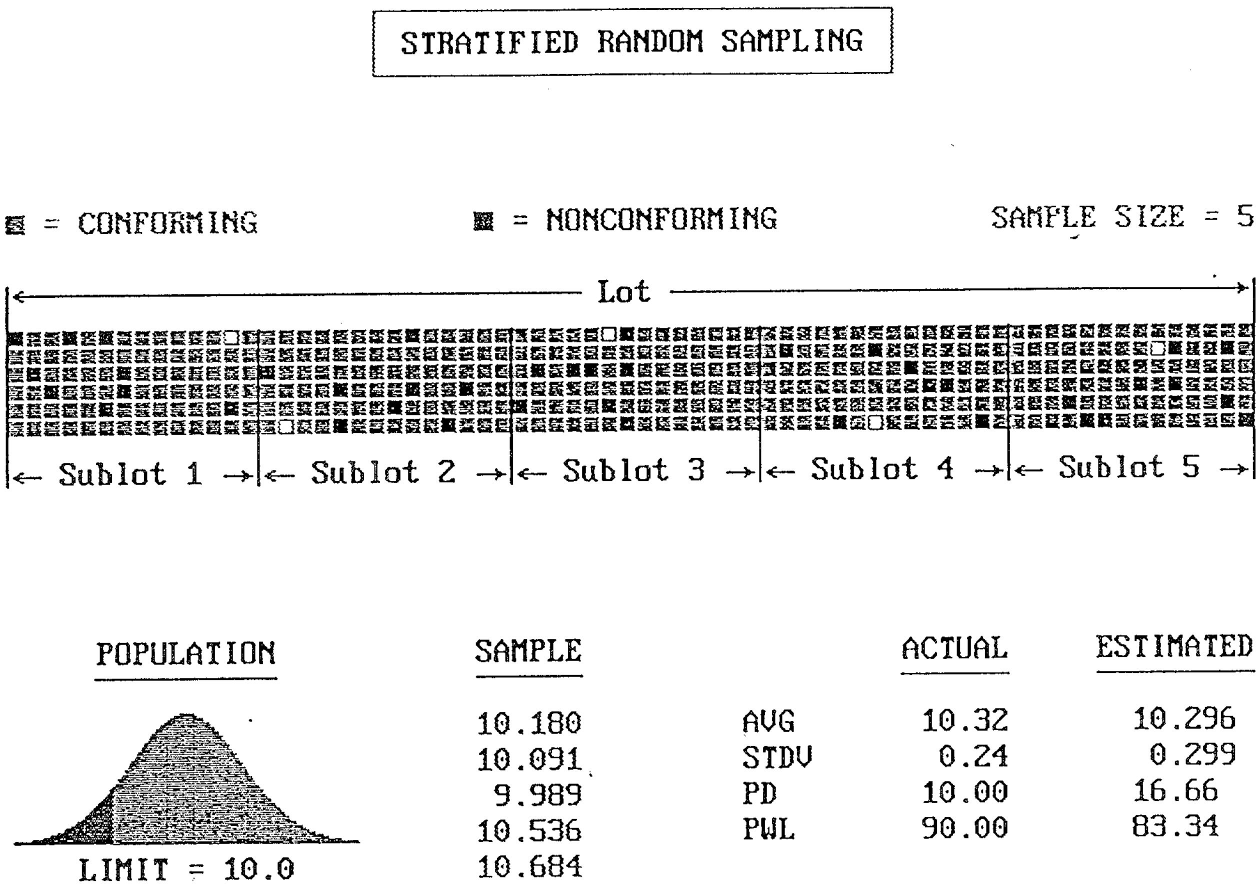


Figure 8.2. Program PAVESAMP display depicting pavement of acceptable quality.

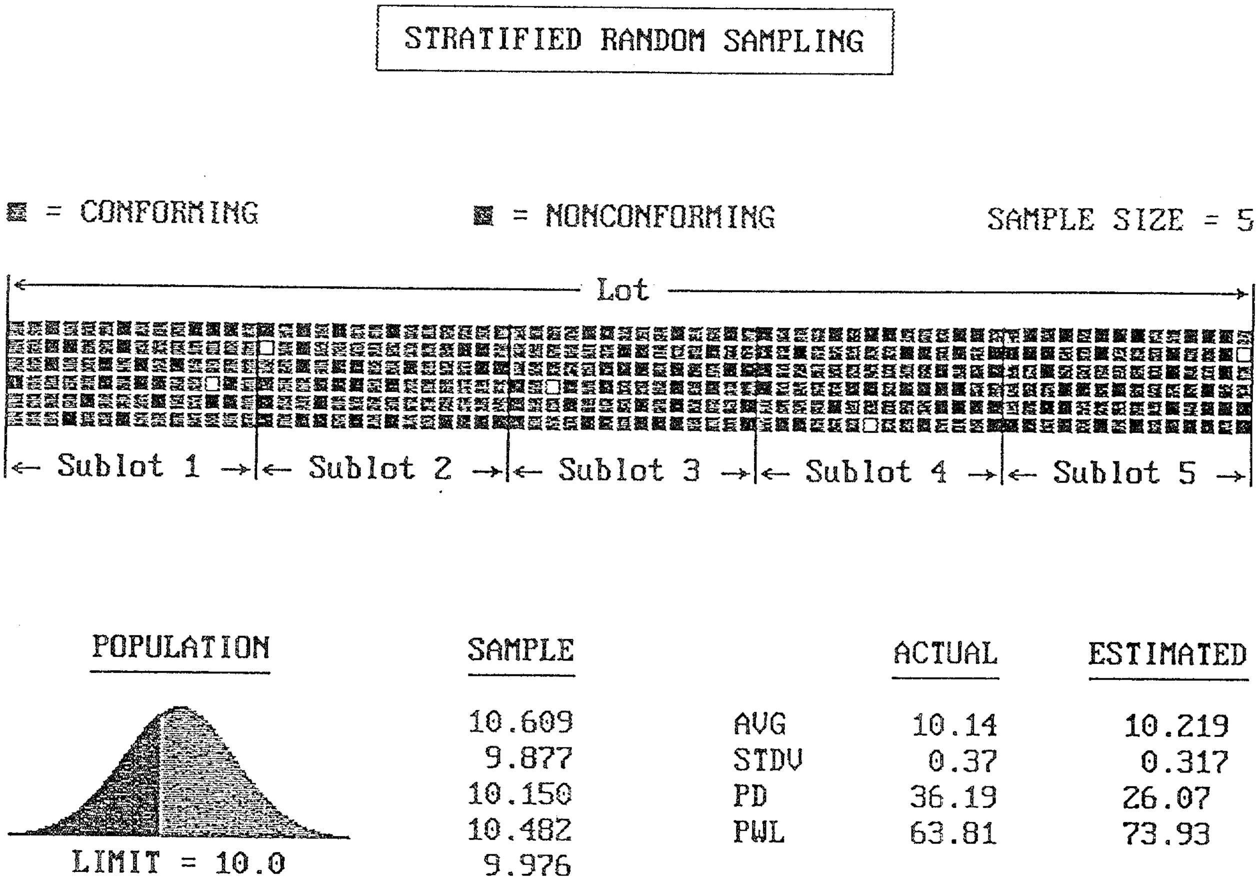


Figure 8.3. Program PAVESAMP display depicting pavement of moderately deficient quality.

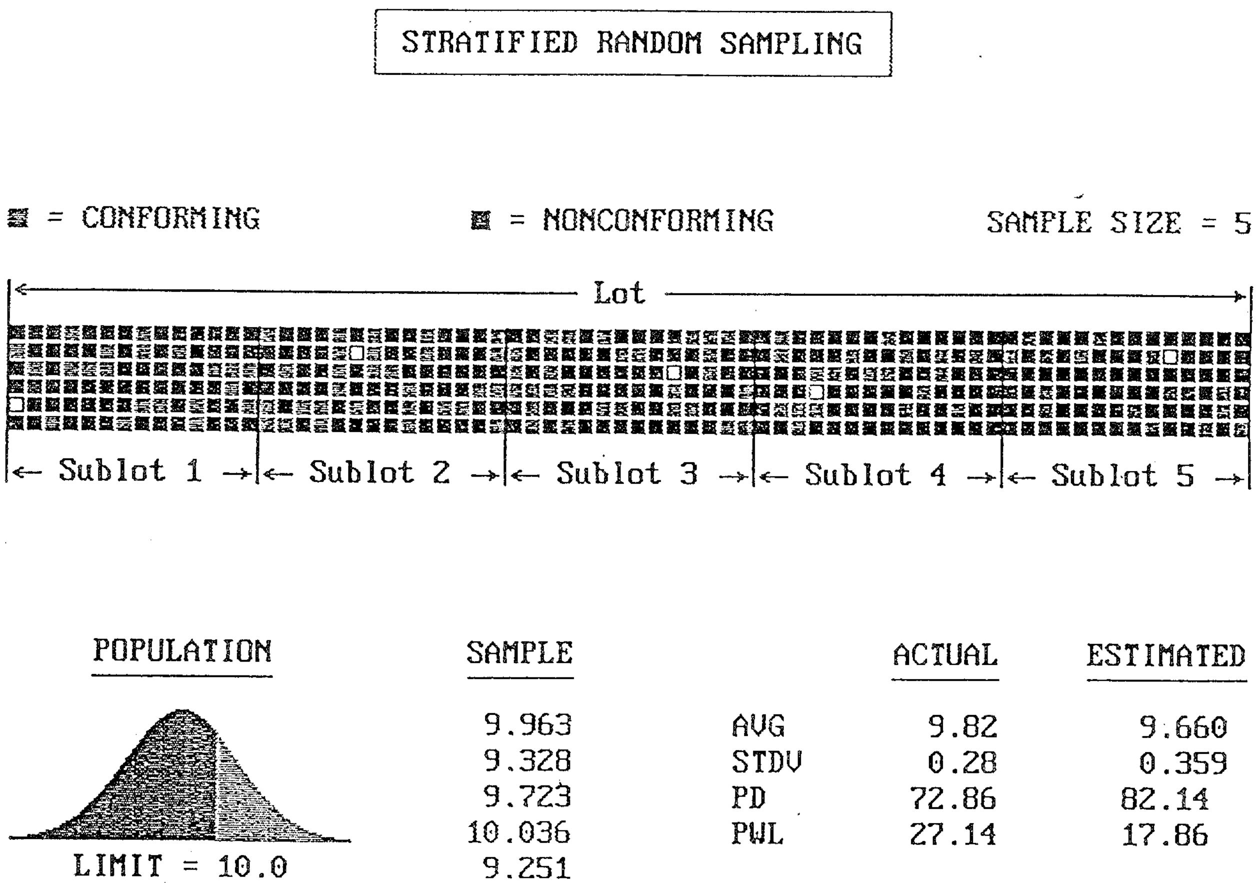


Figure 8.4. Program PAVESAMP display depicting pavement of very poor quality.

the mean, standard deviation, percent defective (PD), and percent within limits (PWL) are displayed in each of these figures. The estimated values computed from the N = 5 tests are also displayed and it can be seen that they all differ somewhat from the true values. This is normal for any statistical estimation process. By running program PAVESAMP several times, it is possible to see how well sample estimates based on this sample size can be expected to reflect the true population values, enabling the user to develop an intuitive feel for both the capabilities and the limitations of this sampling procedure.

Example 8.2 -- Program PAVESAMP Summary Statistics

It can be observed from the results in figures 8.1 through 8.4 that the sample estimates fall both above and below the true population values. This is the expected result with unbiased estimation procedures although, strictly speaking, it is the sample variance and not the sample standard deviation that is the unbiased estimator. There is a tendency for the sample standard deviation to have a small downward bias.

To demonstrate the tendency for the averages of the sample estimates to converge on the averages of the true population values as the number of lots increases, program PAVESAMP keeps a record of the results from each run. A summary may be viewed at any time by responding with <N> or <n> when the prompt "Run Again? <Y/N>" appears at the end of each run. Table 8.1 presents summary results that were obtained after an increasingly larger number of runs.

Table 8.1. Summary statistics produced by program PAVESAMP.

	AVERAGES FOR 10 RUNS		AVERAGES FOR 100 RUNS	
	ACTUAL	ESTIMATED	ACTUAL	ESTIMATED
AVG	10.22	10.24	10.22	10.23
STDV	0.25	0.22	0.25	0.24
PD	17.95	15.58	18.30	17.83
PWL	82.05	84.42	81.70	82.17

	AVERAGES FOR 1000 RUNS		AVERAGES FOR 10000 RUNS	
	ACTUAL	ESTIMATED	ACTUAL	ESTIMATED
AVG	10.22	10.23	10.23	10.23
STDV	0.25	0.24	0.25	0.24
PD	18.34	18.05	18.37	18.40
PWL	81.66	81.95	81.63	81.60

This tendency for the sample estimates to converge on the true population values is an especially important property when statistical measures are used with pay adjustment acceptance procedures. As the number of lots for a project increases, the increased total sample size produces a better estimate of average project quality and a correspondingly better assessment of the appropriate average pay factor.

LAMIA'S LAMENT

"You haven't told me yet," said Lady Nuttal, "what it is your fiancé does for a living."

"He's a statistician," replied Lamia, with an annoying sense of being on the defensive.

Lady Nuttal was obviously taken aback. It had not occurred to her that statisticians entered into normal social relationships. The species, she would have surmised, was perpetuated in some collateral manner, like mules.

"But Aunt Sara, it's a very interesting profession," said Lamia warmly.

"I don't doubt it," said her aunt, who obviously doubted it very much. "To express anything important in mere figures is so plainly impossible that there must be endless scope for well paid advice on how to do it. But don't you think that life with a statistician would be rather, shall we say, humdrum?"

Lamia was silent. She felt reluctant to discuss the surprising depth of emotional possibility which she had discovered below Edward's numerical veneer.

"It's not the figures themselves," she said finally, "it's what you do with them that matters."

(K. A. C. Manderville, *The Undoing of Lamia Gurdleneck*)

APPENDIX

ESTIMATION OF PD AND PWL

FOR SAMPLE SIZES OF

N = 3 TO N = 30

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 3 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.72	49.45	49.17	48.90	48.62	48.35	48.07	47.79	47.52
0.1	47.24	46.96	46.69	46.41	46.13	45.85	45.58	45.30	45.02	44.74
0.2	44.46	44.18	43.90	43.62	43.34	43.05	42.77	42.49	42.20	41.92
0.3	41.63	41.35	41.06	40.77	40.49	40.20	39.91	39.62	39.33	39.03
0.4	38.74	38.45	38.15	37.85	37.56	37.26	36.96	36.66	36.35	36.05
0.5	35.75	35.44	35.13	34.82	34.51	34.20	33.88	33.57	33.25	32.93
0.6	32.61	32.28	31.96	31.63	31.30	30.97	30.63	30.30	29.96	29.61
0.7	29.27	28.92	28.57	28.22	27.86	27.50	27.13	26.76	26.39	26.02
0.8	25.64	25.25	24.86	24.47	24.07	23.67	23.26	22.84	22.42	21.99
0.9	21.55	21.11	20.66	20.19	19.73	19.25	18.75	18.25	17.74	17.21
1.0	16.67	16.11	15.53	14.93	14.31	13.66	12.98	12.27	11.51	10.71
1.1	9.84	8.89	7.82	6.60	5.08	2.87	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 4 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.67	49.33	49.00	48.67	48.33	48.00	47.67	47.33	47.00
0.1	46.67	46.33	46.00	45.67	45.33	45.00	44.67	44.33	44.00	43.67
0.2	43.33	43.00	42.67	42.33	42.00	41.67	41.33	41.00	40.67	40.33
0.3	40.00	39.67	39.33	39.00	38.67	38.33	38.00	37.67	37.33	37.00
0.4	36.67	36.33	36.00	35.67	35.33	35.00	34.67	34.33	34.00	33.67
0.5	33.33	33.00	32.67	32.33	32.00	31.67	31.33	31.00	30.67	30.33
0.6	30.00	29.67	29.33	29.00	28.67	28.33	28.00	27.67	27.33	27.00
0.7	26.67	26.33	26.00	25.67	25.33	25.00	24.67	24.33	24.00	23.67
0.8	23.33	23.00	22.67	22.33	22.00	21.67	21.33	21.00	20.67	20.33
0.9	20.00	19.67	19.33	19.00	18.67	18.33	18.00	17.67	17.33	17.00
1.0	16.67	16.33	16.00	15.67	15.33	15.00	14.67	14.33	14.00	13.67
1.1	13.33	13.00	12.67	12.33	12.00	11.67	11.33	11.00	10.67	10.33
1.2	10.00	9.67	9.33	9.00	8.67	8.33	8.00	7.67	7.33	7.00
1.3	6.67	6.33	6.00	5.67	5.33	5.00	4.67	4.33	4.00	3.67
1.4	3.33	3.00	2.67	2.33	2.00	1.67	1.33	1.00	0.67	0.33
1.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 5 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.64	49.29	48.93	48.58	48.22	47.87	47.51	47.15	46.80
0.1	46.44	46.09	45.73	45.38	45.02	44.67	44.31	43.96	43.61	43.25
0.2	42.90	42.54	42.19	41.84	41.48	41.13	40.78	40.43	40.08	39.72
0.3	39.37	39.02	38.67	38.32	37.97	37.62	37.28	36.93	36.58	36.23
0.4	35.88	35.54	35.19	34.85	34.50	34.16	33.81	33.47	33.13	32.78
0.5	32.44	32.10	31.76	31.42	31.08	30.74	30.40	30.06	29.73	29.39
0.6	29.05	28.72	28.39	28.05	27.72	27.39	27.06	26.73	26.40	26.07
0.7	25.74	25.41	25.09	24.76	24.44	24.11	23.79	23.47	23.15	22.83
0.8	22.51	22.19	21.87	21.56	21.24	20.93	20.62	20.31	20.00	19.69
0.9	19.38	19.07	18.77	18.46	18.16	17.86	17.55	17.26	16.96	16.66
1.0	16.36	16.07	15.78	15.48	15.19	14.91	14.62	14.33	14.05	13.76
1.1	13.48	13.20	12.93	12.65	12.37	12.10	11.83	11.56	11.29	11.02
1.2	10.76	10.50	10.23	9.97	9.72	9.46	9.21	8.96	8.71	8.46
1.3	8.21	7.97	7.73	7.49	7.25	7.02	6.79	6.56	6.33	6.10
1.4	5.88	5.66	5.44	5.23	5.02	4.81	4.60	4.39	4.19	3.99
1.5	3.80	3.61	3.42	3.23	3.05	2.87	2.69	2.52	2.35	2.19
1.6	2.03	1.87	1.72	1.57	1.42	1.28	1.15	1.02	0.89	0.77
1.7	0.66	0.55	0.45	0.36	0.27	0.19	0.12	0.06	0.02	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE SAMPLE SIZE 6 STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.63	49.27	48.90	48.53	48.16	47.80	47.43	47.06	46.70
0.1	46.33	45.96	45.60	45.23	44.86	44.50	44.13	43.77	43.40	43.04
0.2	42.68	42.31	41.95	41.59	41.22	40.86	40.50	40.14	39.78	39.42
0.3	39.06	38.70	38.34	37.98	37.62	37.27	36.91	36.55	36.20	35.84
0.4	35.49	35.14	34.79	34.43	34.08	33.73	33.38	33.04	32.69	32.34
0.5	32.00	31.65	31.31	30.96	30.62	30.28	29.94	29.60	29.26	28.93
0.6	28.59	28.25	27.92	27.59	27.26	26.92	26.60	26.27	25.94	25.61
0.7	25.29	24.96	24.64	24.32	24.00	23.68	23.37	23.05	22.74	22.42
0.8	22.11	21.80	21.49	21.18	20.88	20.57	20.27	19.97	19.67	19.37
0.9	19.07	18.78	18.49	18.19	17.90	17.61	17.33	17.04	16.76	16.48
1.0	16.20	15.92	15.64	15.37	15.09	14.82	14.55	14.29	14.02	13.76
1.1	13.50	13.24	12.98	12.72	12.47	12.22	11.97	11.72	11.47	11.23
1.2	10.99	10.75	10.51	10.28	10.04	9.81	9.58	9.36	9.13	8.91
1.3	8.69	8.48	8.26	8.05	7.84	7.63	7.42	7.22	7.02	6.82
1.4	6.63	6.43	6.24	6.05	5.87	5.68	5.50	5.33	5.15	4.98
1.5	4.81	4.64	4.47	4.31	4.15	4.00	3.84	3.69	3.54	3.40
1.6	3.25	3.11	2.97	2.84	2.71	2.58	2.45	2.33	2.21	2.09
1.7	1.98	1.87	1.76	1.66	1.55	1.45	1.36	1.27	1.18	1.09
1.8	1.01	0.93	0.85	0.78	0.71	0.64	0.57	0.51	0.46	0.40
1.9	0.35	0.30	0.26	0.22	0.18	0.15	0.12	0.09	0.07	0.05
2.0	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 7 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.63	49.25	48.88	48.50	48.13	47.76	47.38	47.01	46.63
0.1	46.26	45.89	45.51	45.14	44.77	44.40	44.03	43.65	43.28	42.91
0.2	42.54	42.17	41.80	41.44	41.07	40.70	40.33	39.97	39.60	39.23
0.3	38.87	38.50	38.14	37.78	37.42	37.06	36.69	36.33	35.98	35.62
0.4	35.26	34.90	34.55	34.19	33.84	33.49	33.13	32.78	32.43	32.08
0.5	31.74	31.39	31.04	30.70	30.36	30.01	29.67	29.33	28.99	28.66
0.6	28.32	27.98	27.65	27.32	26.99	26.66	26.33	26.00	25.68	25.35
0.7	25.03	24.71	24.39	24.07	23.75	23.44	23.12	22.81	22.50	22.19
0.8	21.88	21.58	21.27	20.97	20.67	20.37	20.07	19.78	19.48	19.19
0.9	18.90	18.61	18.33	18.04	17.76	17.48	17.20	16.92	16.65	16.37
1.0	16.10	15.83	15.56	15.30	15.03	14.77	14.51	14.26	14.00	13.75
1.1	13.49	13.25	13.00	12.75	12.51	12.27	12.03	11.79	11.56	11.33
1.2	11.10	10.87	10.65	10.42	10.20	9.98	9.77	9.55	9.34	9.13
1.3	8.93	8.72	8.52	8.32	8.12	7.92	7.73	7.54	7.35	7.17
1.4	6.98	6.80	6.62	6.45	6.27	6.10	5.93	5.77	5.60	5.44
1.5	5.28	5.13	4.97	4.82	4.67	4.52	4.38	4.24	4.10	3.96
1.6	3.83	3.69	3.57	3.44	3.31	3.19	3.07	2.95	2.84	2.73
1.7	2.62	2.51	2.41	2.30	2.20	2.11	2.01	1.92	1.83	1.74
1.8	1.65	1.57	1.49	1.41	1.34	1.26	1.19	1.12	1.06	0.99
1.9	0.93	0.87	0.81	0.76	0.70	0.65	0.60	0.56	0.51	0.47
2.0	0.43	0.39	0.36	0.32	0.29	0.26	0.23	0.21	0.18	0.16
2.1	0.14	0.12	0.10	0.08	0.07	0.06	0.05	0.04	0.03	0.02
2.2	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 8 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.24	48.86	48.49	48.11	47.73	47.35	46.97	46.59
0.1	46.22	45.84	45.46	45.08	44.71	44.33	43.96	43.58	43.21	42.83
0.2	42.46	42.08	41.71	41.34	40.97	40.59	40.22	39.85	39.48	39.11
0.3	38.75	38.38	38.01	37.65	37.28	36.92	36.55	36.19	35.83	35.47
0.4	35.11	34.75	34.39	34.04	33.68	33.33	32.97	32.62	32.27	31.92
0.5	31.57	31.22	30.87	30.53	30.18	29.84	29.50	29.16	28.82	28.48
0.6	28.15	27.81	27.48	27.15	26.82	26.49	26.16	25.83	25.51	25.19
0.7	24.86	24.54	24.23	23.91	23.59	23.28	22.97	22.66	22.35	22.04
0.8	21.74	21.44	21.14	20.84	20.54	20.24	19.95	19.66	19.37	19.08
0.9	18.79	18.51	18.23	17.95	17.67	17.39	17.12	16.85	16.57	16.31
1.0	16.04	15.78	15.51	15.25	15.00	14.74	14.49	14.24	13.99	13.74
1.1	13.49	13.25	13.01	12.77	12.54	12.30	12.07	11.84	11.61	11.39
1.2	11.17	10.94	10.73	10.51	10.30	10.09	9.88	9.67	9.47	9.26
1.3	9.06	8.87	8.67	8.48	8.29	8.10	7.91	7.73	7.55	7.37
1.4	7.19	7.02	6.85	6.68	6.51	6.35	6.19	6.03	5.87	5.71
1.5	5.56	5.41	5.26	5.12	4.97	4.83	4.69	4.56	4.42	4.29
1.6	4.16	4.03	3.91	3.79	3.67	3.55	3.43	3.32	3.21	3.10
1.7	2.99	2.89	2.79	2.69	2.59	2.49	2.40	2.31	2.22	2.13
1.8	2.04	1.96	1.88	1.80	1.72	1.65	1.58	1.51	1.44	1.37
1.9	1.31	1.24	1.18	1.12	1.07	1.01	0.96	0.91	0.86	0.81
2.0	0.76	0.72	0.67	0.63	0.59	0.55	0.52	0.48	0.45	0.42
2.1	0.39	0.36	0.33	0.30	0.28	0.26	0.23	0.21	0.19	0.17
2.2	0.16	0.14	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.05
2.3	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 9 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.24	48.85	48.47	48.09	47.71	47.33	46.95	46.57
0.1	46.18	45.80	45.42	45.04	44.66	44.29	43.91	43.53	43.15	42.77
0.2	42.40	42.02	41.64	41.27	40.89	40.52	40.15	39.77	39.40	39.03
0.3	38.66	38.29	37.92	37.55	37.19	36.82	36.46	36.09	35.73	35.37
0.4	35.00	34.64	34.29	33.93	33.57	33.21	32.86	32.51	32.15	31.80
0.5	31.45	31.10	30.76	30.41	30.07	29.72	29.38	29.04	28.70	28.36
0.6	28.03	27.69	27.36	27.03	26.70	26.37	26.04	25.72	25.39	25.07
0.7	24.75	24.43	24.11	23.80	23.49	23.17	22.86	22.56	22.25	21.94
0.8	21.64	21.34	21.04	20.75	20.45	20.16	19.87	19.58	19.29	19.00
0.9	18.72	18.44	18.16	17.88	17.61	17.33	17.06	16.79	16.53	16.26
1.0	16.00	15.74	15.48	15.23	14.97	14.72	14.47	14.22	13.98	13.73
1.1	13.49	13.26	13.02	12.79	12.55	12.32	12.10	11.87	11.65	11.43
1.2	11.21	11.00	10.78	10.57	10.36	10.15	9.95	9.75	9.55	9.35
1.3	9.16	8.96	8.77	8.59	8.40	8.22	8.04	7.86	7.68	7.51
1.4	7.33	7.17	7.00	6.83	6.67	6.51	6.35	6.20	6.04	5.89
1.5	5.74	5.60	5.45	5.31	5.17	5.03	4.90	4.77	4.64	4.51
1.6	4.38	4.26	4.14	4.02	3.90	3.78	3.67	3.56	3.45	3.34
1.7	3.24	3.14	3.03	2.94	2.84	2.75	2.65	2.56	2.47	2.39
1.8	2.30	2.22	2.14	2.06	1.98	1.91	1.84	1.76	1.70	1.63
1.9	1.56	1.50	1.44	1.37	1.32	1.26	1.20	1.15	1.10	1.05
2.0	1.00	0.95	0.90	0.86	0.82	0.77	0.73	0.70	0.66	0.62
2.1	0.59	0.55	0.52	0.49	0.46	0.43	0.41	0.38	0.36	0.33
2.2	0.31	0.29	0.27	0.25	0.23	0.21	0.20	0.18	0.17	0.15
2.3	0.14	0.13	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.05
2.4	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.5	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 10 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.23	48.85	48.46	48.08	47.70	47.31	46.93	46.54
0.1	46.16	45.78	45.40	45.01	44.63	44.25	43.87	43.49	43.11	42.73
0.2	42.35	41.97	41.60	41.22	40.84	40.47	40.09	39.72	39.34	38.97
0.3	38.60	38.23	37.86	37.49	37.12	36.75	36.38	36.02	35.65	35.29
0.4	34.93	34.57	34.21	33.85	33.49	33.13	32.78	32.42	32.07	31.72
0.5	31.37	31.02	30.67	30.32	29.98	29.64	29.29	28.95	28.61	28.28
0.6	27.94	27.60	27.27	26.94	26.61	26.28	25.96	25.63	25.31	24.99
0.7	24.67	24.35	24.03	23.72	23.41	23.10	22.79	22.48	22.18	21.87
0.8	21.57	21.27	20.98	20.68	20.39	20.10	19.81	19.52	19.23	18.95
0.9	18.67	18.39	18.11	17.84	17.56	17.29	17.03	16.76	16.49	16.23
1.0	15.97	15.72	15.46	15.21	14.96	14.71	14.46	14.22	13.97	13.73
1.1	13.50	13.26	13.03	12.80	12.57	12.34	12.12	11.90	11.68	11.46
1.2	11.24	11.03	10.82	10.61	10.41	10.21	10.00	9.81	9.61	9.42
1.3	9.22	9.03	8.85	8.66	8.48	8.30	8.12	7.95	7.77	7.60
1.4	7.44	7.27	7.10	6.94	6.78	6.63	6.47	6.32	6.17	6.02
1.5	5.87	5.73	5.59	5.45	5.31	5.18	5.05	4.92	4.79	4.66
1.6	4.54	4.41	4.30	4.18	4.06	3.95	3.84	3.73	3.62	3.52
1.7	3.41	3.31	3.21	3.11	3.02	2.93	2.83	2.74	2.66	2.57
1.8	2.49	2.40	2.32	2.25	2.17	2.09	2.02	1.95	1.88	1.81
1.9	1.75	1.68	1.62	1.56	1.50	1.44	1.38	1.33	1.27	1.22
2.0	1.17	1.12	1.07	1.03	0.98	0.94	0.90	0.86	0.82	0.78
2.1	0.74	0.71	0.67	0.64	0.61	0.58	0.55	0.52	0.49	0.46
2.2	0.44	0.41	0.39	0.37	0.34	0.32	0.30	0.29	0.27	0.25
2.3	0.23	0.22	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.12
2.4	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05
2.5	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.6	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE					SAMPLE SIZE 11	STANDARD DEVIATION METHOD				
Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.23	48.84	48.46	48.07	47.68	47.30	46.91	46.53
0.1	46.14	45.76	45.38	44.99	44.61	44.23	43.84	43.46	43.08	42.70
0.2	42.32	41.94	41.56	41.18	40.80	40.42	40.05	39.67	39.30	38.92
0.3	38.55	38.18	37.81	37.44	37.07	36.70	36.33	35.96	35.60	35.23
0.4	34.87	34.51	34.15	33.79	33.43	33.07	32.71	32.36	32.01	31.65
0.5	31.30	30.95	30.60	30.26	29.91	29.57	29.23	28.89	28.55	28.21
0.6	27.87	27.54	27.21	26.88	26.55	26.22	25.89	25.57	25.25	24.92
0.7	24.61	24.29	23.97	23.66	23.35	23.04	22.73	22.43	22.12	21.82
0.8	21.52	21.22	20.93	20.63	20.34	20.05	19.76	19.48	19.19	18.91
0.9	18.63	18.35	18.08	17.80	17.53	17.26	17.00	16.73	16.47	16.21
1.0	15.95	15.70	15.44	15.19	14.94	14.70	14.45	14.21	13.97	13.73
1.1	13.50	13.26	13.03	12.81	12.58	12.36	12.13	11.91	11.70	11.48
1.2	11.27	11.06	10.85	10.65	10.44	10.24	10.05	9.85	9.66	9.46
1.3	9.28	9.09	8.90	8.72	8.54	8.36	8.19	8.02	7.85	7.68
1.4	7.51	7.35	7.19	7.03	6.87	6.71	6.56	6.41	6.26	6.12
1.5	5.97	5.83	5.69	5.55	5.42	5.29	5.16	5.03	4.90	4.78
1.6	4.65	4.53	4.41	4.30	4.18	4.07	3.96	3.85	3.75	3.64
1.7	3.54	3.44	3.34	3.25	3.15	3.06	2.97	2.88	2.79	2.71
1.8	2.62	2.54	2.46	2.38	2.31	2.23	2.16	2.09	2.02	1.95
1.9	1.88	1.82	1.76	1.69	1.63	1.58	1.52	1.46	1.41	1.36
2.0	1.30	1.25	1.21	1.16	1.11	1.07	1.02	0.98	0.94	0.90
2.1	0.86	0.83	0.79	0.75	0.72	0.69	0.66	0.63	0.60	0.57
2.2	0.54	0.51	0.49	0.46	0.44	0.42	0.40	0.37	0.35	0.33
2.3	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.21	0.19	0.18
2.4	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.10	0.09	0.09
2.5	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04
2.6	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01
2.7	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 12 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.23	48.84	48.45	48.06	47.68	47.29	46.90	46.52
0.1	46.13	45.74	45.36	44.97	44.59	44.20	43.82	43.44	43.05	42.67
0.2	42.29	41.91	41.53	41.15	40.77	40.39	40.01	39.64	39.26	38.89
0.3	38.51	38.14	37.77	37.39	37.02	36.65	36.29	35.92	35.55	35.19
0.4	34.82	34.46	34.10	33.74	33.38	33.02	32.66	32.31	31.96	31.60
0.5	31.25	30.90	30.55	30.21	29.86	29.52	29.18	28.83	28.50	28.16
0.6	27.82	27.49	27.16	26.82	26.50	26.17	25.84	25.52	25.20	24.88
0.7	24.56	24.24	23.93	23.61	23.30	22.99	22.69	22.38	22.08	21.78
0.8	21.48	21.18	20.89	20.59	20.30	20.01	19.73	19.44	19.16	18.88
0.9	18.60	18.32	18.05	17.78	17.51	17.24	16.98	16.71	16.45	16.19
1.0	15.94	15.68	15.43	15.18	14.94	14.69	14.45	14.21	13.97	13.73
1.1	13.50	13.27	13.04	12.81	12.59	12.37	12.15	11.93	11.71	11.50
1.2	11.29	11.08	10.88	10.67	10.47	10.27	10.08	9.88	9.69	9.50
1.3	9.32	9.13	8.95	8.77	8.59	8.41	8.24	8.07	7.90	7.73
1.4	7.57	7.41	7.25	7.09	6.93	6.78	6.63	6.48	6.34	6.19
1.5	6.05	5.91	5.77	5.64	5.50	5.37	5.24	5.11	4.99	4.86
1.6	4.74	4.62	4.51	4.39	4.28	4.17	4.06	3.95	3.85	3.74
1.7	3.64	3.54	3.45	3.35	3.26	3.16	3.07	2.99	2.90	2.81
1.8	2.73	2.65	2.57	2.49	2.42	2.34	2.27	2.20	2.13	2.06
1.9	1.99	1.93	1.86	1.80	1.74	1.68	1.62	1.57	1.51	1.46
2.0	1.41	1.36	1.31	1.26	1.21	1.17	1.12	1.08	1.04	1.00
2.1	0.96	0.92	0.88	0.85	0.81	0.78	0.75	0.71	0.68	0.65
2.2	0.63	0.60	0.57	0.54	0.52	0.49	0.47	0.45	0.43	0.41
2.3	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.25	0.24
2.4	0.22	0.21 0.20	0.19	0.18	0.16	0.15	0.14	0.14	0.13	
2.5	0.12	0.11	0.10	0.10	0.09	0.08	0.08	0.07	0.07	0.06
2.6	0.06	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2.7	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
2.8	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 13 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.22	48.83	48.45	48.06	47.67	47.28	46.89	46.51
0.1	46.12	45.73	45.35	44.96	44.57	44.19	43.80	43.42	43.04	42.65
0.2	42.27	41.89	41.51	41.13	40.75	40.37	39.99	39.61	39.23	38.86
0.3	38.48	38.11	37.73	37.36	36.99	36.62	36.25	35.88	35.52	35.15
0.4	34.79	34.42	34.06	33.70	33.34	32.98	32.63	32.27	31.92	31.56
0.5	31.21	30.86	30.51	30.17	29.82	29.48	29.13	28.79	28.45	28.12
0.6	27.78	27.45	27.11	26.78	26.45	26.13	25.80	25.48	25.16	24.84
0.7	24.52	24.20	23.89	23.58	23.27	22.96	22.65	22.35	22.04	21.74
0.8	21.45	21.15	20.86	20.56	20.27	19.99	19.70	19.42	19.13	18.85
0.9	18.58	18.30	18.03	17.76	17.49	17.22	16.96	16.70	16.44	16.18
1.0	15.93	15.67	15.42	15.18	14.93	14.69	14.44	14.21	13.97	13.73
1.1	13.50	13.27	13.05	12.82	12.60	12.38	12.16	11.94	11.73	11.52
1.2	11.31	11.10	10.90	10.70	10.50	10.30	10.10	9.91	9.72	9.53
1.3	9.35	9.17	8.98	8.81	8.63	8.45	8.28	8.11	7.95	7.78
1.4	7.62	7.46	7.30	7.14	6.99	6.84	6.69	6.54	6.39	6.25
1.5	6.11	5.97	5.83	5.70	5.57	5.44	5.31	5.18	5.06	4.94
1.6	4.82	4.70	4.58	4.47	4.36	4.25	4.14	4.03	3.93	3.82
1.7	3.72	3.62	3.53	3.43	3.34	3.25	3.16	3.07	2.98	2.90
1.8	2.82	2.74	2.66	2.58	2.50	2.43	2.35	2.28	2.21	2.15
1.9	2.08	2.01	1.95	1.89	1.83	1.77	1.71	1.65	1.60	1.54
2.0	1.49	1.44	1.39	1.34	1.30	1.25	1.21	1.16	1.12	1.08
2.1	1.04	1.00	0.96	0.92	0.89	0.85	0.82	0.79	0.76	0.72
2.2	0.69	0.67	0.64	0.61	0.58	0.56	0.53	0.51	0.49	0.47
2.3	0.45	0.42	0.40	0.39	0.37	0.35	0.33	0.32	0.30	0.29
2.4	0.27	0.26	0.24	0.23	0.22	0.21	0.19	0.18	0.17	0.16
2.5	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09
2.6	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.04
2.7	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
2.8	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2.9	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 14 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.22	48.83	48.44	48.05	47.66	47.27	46.89	46.50
0.1	46.11	45.72	45.33	44.95	44.56	44.17	43.79	43.40	43.02	42.63
0.2	42.25	41.87	41.49	41.11	40.72	40.34	39.97	39.59	39.21	38.83
0.3	38.46	38.08	37.71	37.34	36.96	36.59	36.22	35.85	35.49	35.12
0.4	34.76	34.39	34.03	33.67	33.31	32.95	32.59	32.24	31.88	31.53
0.5	31.18	30.83	30.48	30.13	29.79	29.44	29.10	28.76	28.42	28.08
0.6	27.75	27.41	27.08	26.75	26.42	26.09	25.77	25.45	25.12	24.81
0.7	24.49	24.17	23.86	23.55	23.24	22.93	22.62	22.32	22.02	21.72
0.8	21.42	21.12	20.83	20.54	20.25	19.96	19.68	19.39	19.11	18.84
0.9	18.56	18.28	18.01	17.74	17.48	17.21	16.95	16.69	16.43	16.17
1.0	15.92	15.67	15.42	15.17	14.92	14.68	14.44	14.20	13.97	13.74
1.1	13.50	13.28	13.05	12.83	12.60	12.39	12.17	11.95	11.74	11.53
1.2	11.32	11.12	10.92	10.72	10.52	10.32	10.13	9.94	9.75	9.56
1.3	9.38	9.19	9.01	8.84	8.66	8.49	8.32	8.15	7.98	7.82
1.4	7.66	7.50	7.34	7.18	7.03	6.88	6.73	6.59	6.44	6.30
1.5	6.16	6.02	5.89	5.75	5.62	5.49	5.36	5.24	5.12	4.99
1.6	4.88	4.76	4.64	4.53	4.42	4.31	4.20	4.09	3.99	3.89
1.7	3.79	3.69	3.59	3.50	3.41	3.32	3.23	3.14	3.05	2.97
1.8	2.89	2.81	2.73	2.65	2.57	2.50	2.43	2.35	2.28	2.22
1.9	2.15	2.08	2.02	1.96	1.90	1.84	1.78	1.72	1.67	1.61
2.0	1.56	1.51	1.46	1.41	1.36	1.32	1.27	1.23	1.18	1.14
2.1	1.10	1.06	1.02	0.99	0.95	0.92	0.88	0.85	0.82	0.78
2.2	0.75	0.72	0.69	0.67	0.64	0.61	0.59	0.56	0.54	0.52
2.3	0.50	0.47	0.45	0.43	0.41	0.40	0.38	0.36	0.34	0.33
2.4	0.31	0.30	0.28	0.27	0.26	0.24	0.23	0.22	0.21	0.20
2.5	0.19	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.12	0.11
2.6	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.06	0.06
2.7	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2.8	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
2.9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 15 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.22	48.83	48.44	48.05	47.66	47.27	46.88	46.49
0.1	46.10	45.71	45.33	44.94	44.55	44.16	43.78	43.39	43.01	42.62
0.2	42.24	41.85	41.47	41.09	40.71	40.33	39.95	39.57	39.19	38.81
0.3	38.44	38.06	37.69	37.31	36.94	36.57	36.20	35.83	35.46	35.10
0.4	34.73	34.37	34.00	33.64	33.28	32.92	32.57	32.21	31.85	31.50
0.5	31.15	30.80	30.45	30.10	29.76	29.41	29.07	28.73	28.39	28.05
0.6	27.72	27.39	27.05	26.72	26.39	26.07	25.74	25.42	25.10	24.78
0.7	24.46	24.15	23.83	23.52	23.21	22.90	22.60	22.30	21.99	21.70
0.8	21.40	21.10	20.81	20.52	20.23	19.94	19.66	19.38	19.10	18.82
0.9	18.54	18.27	18.00	17.73	17.46	17.20	16.94	16.68	16.42	16.16
1.0	15.91	15.66	15.41	15.17	14.92	14.68	14.44	14.20	13.97	13.74
1.1	13.51	13.28	13.05	12.83	12.61	12.39	12.18	11.96	11.75	11.54
1.2	11.34	11.13	10.93	10.73	10.53	10.34	10.15	9.96	9.77	9.58
1.3	9.40	9.22	9.04	8.86	8.69	8.52	8.35	8.18	8.01	7.85
1.4	7.69	7.53	7.37	7.22	7.07	6.92	6.77	6.63	6.48	6.34
1.5	6.20	6.06	5.93	5.80	5.67	5.54	5.41	5.29	5.16	5.04
1.6	4.92	4.81	4.69	4.58	4.47	4.36	4.25	4.15	4.05	3.94
1.7	3.84	3.75	3.65	3.56	3.46	3.37	3.28	3.20	3.11	3.03
1.8	2.94	2.86	2.79	2.71	2.63	2.56	2.49	2.41	2.34	2.28
1.9	2.21	2.14	2.08	2.02	1.96	1.90	1.84	1.78	1.73	1.67
2.0	1.62	1.57	1.52	1.47	1.42	1.37	1.33	1.28	1.24	1.20
2.1	1.16	1.12	1.08	1.04	1.00	0.97	0.93	0.90	0.87	0.83
2.2	0.80	0.77	0.74	0.71	0.69	0.66	0.63	0.61	0.58	0.56
2.3	0.54	0.52	0.49	0.47	0.45	0.43	0.42	0.40	0.38	0.36
2.4	0.35	0.33	0.32	0.30	0.29	0.27	0.26	0.25	0.24	0.23
2.5	0.21	0.20	0.19	0.18	0.17	0.17	0.16	0.15	0.14	0.13
2.6	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.07
2.7	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04
2.8	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
2.9	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.0	0.01	0.01	0.01	0.0	0 0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 16 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.22	48.83	48.44	48.05	47.66	47.26	46.87	46.48
0.1	46.10	45.71	45.32	44.93	44.54	44.15	43.77	43.38	42.99	42.61
0.2	42.22	41.84	41.46	41.07	40.69	40.31	39.93	39.55	39.17	38.79
0.3	38.42	38.04	37.67	37.29	36.92	36.55	36.18	35.81	35.44	35.07
0.4	34.71	34.34	33.98	33.62	33.26	32.90	32.54	32.19	31.83	31.48
0.5	31.13	30.78	30.43	30.08	29.73	29.39	29.05	28.71	28.37	28.03
0.6	27.70	27.36	27.03	26.70	26.37	26.04	25.72	25.40	25.08	24.76
0.7	24.44	24.12	23.81	23.50	23.19	22.88	22.58	22.28	21.98	21.68
0.8	21.38	21.09	20.79	20.50	20.21	19.93	19.64	19.36	19.08	18.81
0.9	18.53	18.26	17.99	17.72	17.45	17.19	16.93	16.67	16.41	16.16
1.0	15.90	15.65	15.41	15.16	14.92	14.68	14.44	14.20	13.97	13.74
1.1	13.51	13.28	13.06	12.84	12.62	12.40	12.18	11.97	11.76	11.55
1.2	11.35	11.14	10.94	10.74	10.55	10.35	10.16	9.97	9.79	9.60
1.3	9.42	9.24	9.06	8.88	8.71	8.54	8.37	8.20	8.04	7.88
1.4	7.72	7.56	7.40	7.25	7.10	6.95	6.80	6.66	6.52	6.38
1.5	6.24	6.10	5.97	5.83	5.70	5.58	5.45	5.33	5.20	5.08
1.6	4.97	4.85	4.74	4.62	4.51	4.40	4.30	4.19	4.09	3.99
1.7	3.89	3.79	3.70	3.60	3.51	3.42	3.33	3.25	3.16	3.08
1.8	2.99	2.91	2.83	2.76	2.68	2.61	2.54	2.46	2.39	2.33
1.9	2.26	2.19	2.13	2.07	2.01	1.95	1.89	1.83	1.78	1.72
2.0	1.67	1.62	1.57	1.52	1.47	1.42	1.38	1.33	1.29	1.25
2.1	1.20	1.16	1.12	1.09	1.05	1.01	0.98	0.94	0.91	0.88
2.2	0.85	0.81	0.78	0.76	0.73	0.70	0.67	0.65	0.62	0.60
2.3	0.58	0.55	0.53	0.51	0.49	0.47	0.45	0.43	0.41	0.40
2.4	0.38	0.36	0.35	0.33	0.32	0.30	0.29	0.28	0.26	0.25
2.5	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17	0.16	0.15
2.6	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.09	0.09
2.7	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
2.8	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02
2.9	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
3.0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00

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PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 17 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.22	48.83	48.43	48.04	47.65	47.26	46.87	46.48
0.1	46.09	45.70	45.31	44.92	44.53	44.15	43.76	43.37	42.98	42.60
0.2	42.21	41.83	41.44	41.06	40.68	40.30	39.92	39.54	39.16	38.78
0.3	38.40	38.03	37.65	37.28	36.90	36.53	36.16	35.79	35.42	35.06
0.4	34.69	34.33	33.96	33.60	33.24	32.88	32.52	32.17	31.81	31.46
0.5	31.11	30.76	30.41	30.06	29.71	29.37	29.03	28.69	28.35	28.01
0.6	27.68	27.34	27.01	26.68	26.35	26.02	25.70	25.38	25.06	24.74
0.7	24.42	24.11	23.79	23.48	23.17	22.87	22.56	22.26	21.96	21.66
0.8	21.36	21.07	20.78	20.49	20.20	19.92	19.63	19.35	19.07	18.79
0.9	18.52	18.25	17.98	17.71	17.44	17.18	16.92	16.66	16.41	16.15
1.0	15.90	15.65	15.40	15.16	14.92	14.68	14.44	14.20	13.97	13.74
1.1	13.51	13.29	13.06	12.84	12.62	12.40	12.19	11.98	11.77	11.56
1.2	11.36	11.15	10.95	10.76	10.56	10.37	10.18	9.99	9.80	9.62
1.3	9.44	9.26	9.08	8.90	8.73	8.56	8.39	8.23	8.06	7.90
1.4	7.74	7.58	7.43	7.28	7.13	6.98	6.83	6.69	6.55	6.41
1.5	6.27	6.13	6.00	5.87	5.74	5.61	5.48	5.36	5.24	5.12
1.6	5.00	4.89	4.77	4.66	4.55	4.44	4.34	4.23	4.13	4.03
1.7	3.93	3.83	3.74	3.64	3.55	3.46	3.37	3.29	3.20	3.12
1.8	3.04	2.96	2.88	2.80	2.72	2.65	2.58	2.51	2.44	2.37
1.9	2.30	2.24	2.17	2.11	2.05	1.99	1.93	1.87	1.82	1.76
2.0	1.71	1.66	1.61	1.56	1.51	1.46	1.42	1.37	1.33	1.29
2.1	1.24	1.20	1.16	1.12	1.09	1.05	1.02	0.98	0.95	0.91
2.2	0.88	0.85	0.82	0.79	0.76	0.74	0.71	0.68	0.66	0.63
2.3	0.61	0.59	0.56	0.54	0.52	0.50	0.48	0.46	0.44	0.42
2.4	0.41	0.39	0.37	0.36	0.34	0.33	0.31	0.30	0.29	0.27
2.5	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17
2.6	0.16	0.15	0.15	0.14	0.13	0.13	0.12	0.11	0.11	0.10
2.7	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06
2.8	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03
2.9	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
3.0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.1	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 18 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.22	48.82	48.43	48.04	47.65	47.26	46.87	46.48
0.1	46.08	45.69	45.30	44.92	44.53	44.14	43.75	43.36	42.98	42.59
0.2	42.20	41.82	41.43	41.05	40.67	40.29	39.91	39.53	39.15	38.77
0.3	38.39	38.01	37.64	37.26	36.89	36.52	36.15	35.78	35.41	35.04
0.4	34.67	34.31	33.95	33.58	33.22	32.86	32.51	32.15	31.79	31.44
0.5	31.09	30.74	30.39	30.04	29.70	29.35	29.01	28.67	28.33	27.99
0.6	27.66	27.32	26.99	26.66	26.33	26.01	25.68	25.36	25.04	24.72
0.7	24.41	24.09	23.78	23.47	23.16	22.85	22.55	22.25	21.95	21.65
0.8	21.35	21.06	20.77	20.48	20.19	19.90	19.62	19.34	19.06	18.79
0.9	18.51	18.24	17.97	17.70	17.44	17.18	16.91	16.66	16.40	16.15
1.0	15.90	15.65	15.40	15.16	14.92	14.68	14.44	14.20	13.97	13.74
1.1	13.51	13.29	13.07	12.84	12.63	12.41	12.20	11.99	11.78	11.57
1.2	11.37	11.16	10.96	10.77	10.57	10.38	10.19	10.00	9.81	9.63
1.3	9.45	9.27	9.09	8.92	8.75	8.58	8.41	8.25	8.08	7.92
1.4	7.76	7.61	7.45	7.30	7.15	7.00	6.86	6.71	6.57	6.43
1.5	6.29	6.16	6.03	5.90	5.77	5.64	5.51	5.39	5.27	5.15
1.6	5.03	4.92	4.80	4.69	4.58	4.48	4.37	4.27	4.16	4.06
1.7	3.96	3.87	3.77	3.68	3.59	3.50	3.41	3.32	3.24	3.15
1.8	3.07	2.99	2.91	2.84	2.76	2.69	2.62	2.54	2.47	2.41
1.9	2.34	2.27	2.21	2.15	2.09	2.03	1.97	1.91	1.86	1.80
2.0	1.75	1.70	1.65	1.60	1.55	1.50	1.45	1.41	1.36	1.32
2.1	1.28	1.24	1.20	1.16	1.12	1.08	1.05	1.01	0.98	0.95
2.2	0.91	0.88	0.85	0.82	0.79	0.77	0.74	0.71	0.69	0.66
2.3	0.64	0.61	0.59	0.57	0.55	0.53	0.51	0.49	0.47	0.45
2.4	0.43	0.41	0.40	0.38	0.37	0.35	0.34	0.32	0.31	0.30
2.5	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19
2.6	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.13	0.12	0.11
2.7	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07
2.8	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04
2.9	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
3.0	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 19 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.22	48.82	48.43	48.04	47.65	47.25	46.86	46.47
0.1	46.08	45.69	45.30	44.91	44.52	44.13	43.74	43.36	42.97	42.58
0.2	42.20	41.81	41.43	41.04	40.66	40.28	39.90	39.51	39.13	38.76
0.3	38.38	38.00	37.63	37.25	36.88	36.51	36.13	35.76	35.40	35.03
0.4	34.66	34.30	33.93	33.57	33.21	32.85	32.49	32.13	31.78	31.43
0.5	31.07	30.72	30.37	30.03	29.68	29.34	28.99	28.65	28.31	27.98
0.6	27.64	27.31	26.98	26.65	26.32	25.99	25.67	25.35	25.03	24.71
0.7	24.39	24.08	23.76	23.45	23.15	22.84	22.54	22.23	21.93	21.64
0.8	21.34	21.05	20.75	20.47	20.18	19.89	19.61	19.33	19.05	18.78
0.9	18.50	18.23	17.96	17.70	17.43	17.17	16.91	16.65	16.40	16.14
1.0	15.89	15.64	15.40	15.16	14.91	14.67	14.44	14.20	13.97	13.74
1.1	13.52	13.29	13.07	12.85	12.63	12.41	12.20	11.99	11.78	11.58
1.2	11.37	11.17	10.97	10.78	10.58	10.39	10.20	10.01	9.83	9.64
1.3	9.46	9.29	9.11	8.94	8.76	8.59	8.43	8.26	8.10	7.94
1.4	7.78	7.63	7.47	7.32	7.17	7.02	6.88	6.73	6.59	6.45
1.5	6.32	6.18	6.05	5.92	5.79	5.66	5.54	5.42	5.30	5.18
1.6	5.06	4.95	4.83	4.72	4.61	4.51	4.40	4.30	4.19	4.09
1.7	4.00	3.90	3.80	3.71	3.62	3.53	3.44	3.35	3.27	3.19
1.8	3.11	3.03	2.95	2.87	2.79	2.72	2.65	2.58	2.51	2.44
1.9	2.37	2.31	2.24	2.18	2.12	2.06	2.00	1.94	1.89	1.83
2.0	1.78	1.73	1.68	1.63	1.58	1.53	1.48	1.44	1.39	1.35
2.1	1.31	1.27	1.23	1.19	1.15	1.11	1.08	1.04	1.01	0.98
2.2	0.94	0.91	0.88	0.85	0.82	0.79	0.76	0.74	0.71	0.69
2.3	0.66	0.64	0.62	0.59	0.57	0.55	0.53	0.51	0.49	0.47
2.4	0.45	0.44	0.42	0.40	0.39	0.37	0.36	0.34	0.33	0.31
2.5	0.30	0.29	0.28	0.26	0.25	0.24	0.23	0.22	0.21	0.20
2.6	0.19	0.18	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.13
2.7	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.07
2.8	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04
2.9	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02
3.0	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
3.1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 20 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.43	48.04	47.64	47.25	46.86	46.47
0.1	46.08	45.69	45.30	44.91	44.52	44.13	43.74	43.35	42.96	42.57
0.2	42.19	41.80	41.42	41.03	40.65	40.27	39.89	39.51	39.13	38.75
0.3	38.37	37.99	37.62	37.24	36.87	36.49	36.12	35.75	35.38	35.02
0.4	34.65	34.28	33.92	33.56	33.20	32.84	32.48	32.12	31.77	31.41
0.5	31.06	30.71	30.36	30.01	29.67	29.32	28.98	28.64	28.30	27.96
0.6	27.63	27.30	26.96	26.63	26.31	25.98	25.66	25.33	25.01	24.70
0.7	24.38	24.06	23.75	23.44	23.13	22.83	22.52	22.22	21.92	21.63
0.8	21.33	21.04	20.75	20.46	20.17	19.89	19.60	19.32	19.05	18.77
0.9	18.50	18.23	17.96	17.69	17.43	17.16	16.90	16.65	16.39	16.14
1.0	15.89	15.64	15.40	15.15	14.91	14.67	14.44	14.20	13.97	13.74
1.1	13.52	13.29	13.07	12.85	12.63	12.42	12.21	12.00	11.79	11.58
1.2	11.38	11.18	10.98	10.78	10.59	10.40	10.21	10.02	9.84	9.66
1.3	9.48	9.30	9.12	8.95	8.78	8.61	8.44	8.28	8.12	7.96
1.4	7.80	7.64	7.49	7.34	7.19	7.04	6.90	6.75	6.61	6.48
1.5	6.34	6.20	6.07	5.94	5.81	5.69	5.56	5.44	5.32	5.20
1.6	5.08	4.97	4.86	4.75	4.64	4.53	4.43	4.32	4.22	4.12
1.7	4.02	3.93	3.83	3.74	3.65	3.56	3.47	3.38	3.30	3.21
1.8	3.13	3.05	2.98	2.90	2.82	2.75	2.68	2.61	2.54	2.47
1.9	2.40	2.34	2.27	2.21	2.15	2.09	2.03	1.97	1.92	1.86
2.0	1.81	1.76	1.71	1.66	1.61	1.56	1.51	1.47	1.42	1.38
2.1	1.34	1.30	1.26	1.22	1.18	1.14	1.10	1.07	1.03	1.00
2.2	0.97	0.94	0.90	0.87	0.85	0.82	0.79	0.76	0.74	0.71
2.3	0.68	0.66	0.64	0.61	0.59	0.57	0.55	0.53	0.51	0.49
2.4	0.47	0.45	0.44	0.42	0.40	0.39	0.37	0.36	0.34	0.33
2.5	0.32	0.30	0.29	0.28	0.27	0.26	0.25	0.24	0.23	0.22
2.6	0.21	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.14
2.7	0.13	0.12	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08
2.8	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
2.9	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
3.0	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
3.1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.2	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 21 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.43	48.03	47.64	47.25	46.86	46.47
0.1	46.07	45.68	45.29	44.90	44.51	44.12	43.73	43.34	42.96	42.57
0.2	42.18	41.80	41.41	41.03	40.64	40.26	39.88	39.50	39.12	38.74
0.3	38.36	37.98	37.61	37.23	36.86	36.48	36.11	35.74	35.37	35.00
0.4	34.64	34.27	33.91	33.55	33.18	32.82	32.47	32.11	31.75	31.40
0.5	31.05	30.70	30.35	30.00	29.66	29.31	28.97	28.63	28.29	27.95
0.6	27.62	27.28	26.95	26.62	26.29	25.97	25.64	25.32	25.00	24.68
0.7	24.37	24.05	23.74	23.43	23.12	22.82	22.51	22.21	21.91	21.62
0.8	21.32	21.03	20.74	20.45	20.16	19.88	19.60	19.32	19.04	18.76
0.9	18.49	18.22	17.95	17.69	17.42	17.16	16.90	16.64	16.39	16.14
1.0	15.89	15.64	15.40	15.15	14.91	14.67	14.44	14.20	13.97	13.75
1.1	13.52	13.30	13.07	12.85	12.64	12.42	12.21	12.00	11.79	11.59
1.2	11.39	11.19	10.99	10.79	10.60	10.41	10.22	10.03	9.85	9.67
1.3	9.49	9.31	9.13	8.96	8.79	8.62	8.46	8.29	8.13	7.97
1.4	7.81	7.66	7.50	7.35	7.21	7.06	6.91	6.77	6.63	6.49
1.5	6.36	6.22	6.09	5.96	5.83	5.71	5.58	5.46	5.34	5.22
1.6	5.11	4.99	4.88	4.77	4.66	4.55	4.45	4.34	4.24	4.14
1.7	4.05	3.95	3.86	3.76	3.67	3.58	3.49	3.41	3.32	3.24
1.8	3.16	3.08	3.00	2.92	2.85	2.77	2.70	2.63	2.56	2.49
1.9	2.43	2.36	2.30	2.24	2.17	2.11	2.06	2.00	1.94	1.89
2.0	1.83	1.78	1.73	1.68	1.63	1.58	1.54	1.49	1.45	1.40
2.1	1.36	1.32	1.28	1.24	1.20	1.16	1.13	1.09	1.06	1.02
2.2	0.99	0.96	0.93	0.90	0.87	0.84	0.81	0.78	0.76	0.73
2.3	0.71	0.68	0.66	0.63	0.61	0.59	0.57	0.55	0.53	0.51
2.4	0.49	0.47	0.45	0.44	0.42	0.40	0.39	0.37	0.36	0.35
2.5	0.33	0.32	0.31	0.29	0.28	0.27	0.26	0.25	0.24	0.23
2.6	0.22	0.21	0.20	0.19	0.18	0.18	0.17	0.16	0.15	0.15
2.7	0.14	0.13	0.13	0.12	0.12	0.11	0.10	0.10	0.10	0.09
2.8	0.09	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.05
2.9	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03
3.0	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3.1	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 22 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.43	48.03	47.64	47.25	46.85	46.46
0.1	46.07	45.68	45.29	44.90	44.51	44.12	43.73	43.34	42.95	42.56
0.2	42.18	41.79	41.40	41.02	40.64	40.25	39.87	39.49	39.11	38.73
0.3	38.35	37.97	37.60	37.22	36.85	36.47	36.10	35.73	35.36	34.99
0.4	34.63	34.26	33.90	33.54	33.17	32.81	32.46	32.10	31.74	31.39
0.5	31.04	30.69	30.34	29.99	29.64	29.30	28.96	28.62	28.28	27.94
0.6	27.61	27.27	26.94	26.61	26.28	25.96	25.63	25.31	24.99	24.67
0.7	24.36	24.04	23.73	23.42	23.12	22.81	22.51	22.20	21.91	21.61
0.8	21.31	21.02	20.73	20.44	20.16	19.87	19.59	19.31	19.03	18.76
0.9	18.49	18.21	17.95	17.68	17.42	17.16	16.90	16.64	16.39	16.14
1.0	15.89	15.64	15.39	15.15	14.91	14.67	14.44	14.21	13.97	13.75
1.1	13.52	13.30	13.08	12.86	12.64	12.43	12.21	12.01	11.80	11.59
1.2	11.39	11.19	10.99	10.80	10.61	10.41	10.23	10.04	9.86	9.67
1.3	9.50	9.32	9.14	8.97	8.80	8.63	8.47	8.30	8.14	7.98
1.4	7.83	7.67	7.52	7.37	7.22	7.07	6.93	6.79	6.65	6.51
1.5	6.37	6.24	6.11	5.98	5.85	5.73	5.60	5.48	5.36	5.24
1.6	5.13	5.01	4.90	4.79	4.68	4.57	4.47	4.37	4.26	4.16
1.7	4.07	3.97	3.88	3.78	3.69	3.60	3.52	3.43	3.35	3.26
1.8	3.18	3.10	3.02	2.95	2.87	2.80	2.73	2.65	2.59	2.52
1.9	2.45	2.39	2.32	2.26	2.20	2.14	2.08	2.02	1.97	1.91
2.0	1.86	1.80	1.75	1.70	1.65	1.61	1.56	1.51	1.47	1.43
2.1	1.38	1.34	1.30	1.26	1.22	1.19	1.15	1.11	1.08	1.04
2.2	1.01	0.98	0.95	0.92	0.89	0.86	0.83	0.80	0.77	0.75
2.3	0.72	0.70	0.67	0.65	0.63	0.61	0.59	0.56	0.54	0.53
2.4	0.51	0.49	0.47	0.45	0.44	0.42	0.40	0.39	0.37	0.36
2.5	0.35	0.33	0.32	0.31	0.29	0.28	0.27	0.26	0.25	0.24
2.6	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.16	0.16
2.7	0.15	0.14	0.14	0.13	0.12	0.12	0.11	0.11	0.10	0.10
2.8	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06
2.9	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03
3.0	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
3.1	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE SAMPLE SIZE 23 STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.43	48.03	47.64	47.25	46.85	46.46
0.1	46.07	45.68	45.28	44.89	44.50	44.11	43.72	43.33	42.95	42.56
0.2	42.17	41.78	41.40	41.01	40.63	40.25	39.86	39.48	39.10	38.72
0.3	38.34	37.97	37.59	37.21	36.84	36.47	36.09	35.72	35.35	34.99
0.4	34.62	34.25	33.89	33.53	33.17	32.81	32.45	32.09	31.73	31.38
0.5	31.03	30.68	30.33	29.98	29.64	29.29	28.95	28.61	28.27	27.93
0.6	27.60	27.26	26.93	26.60	26.27	25.95	25.63	25.30	24.98	24.67
0.7	24.35	24.04	23.72	23.41	23.11	22.80	22.50	22.20	21.90	21.60
0.8	21.31	21.01	20.72	20.43	20.15	19.87	19.58	19.30	19.03	18.75
0.9	18.48	18.21	17.94	17.68	17.41	17.15	16.89	16.64	16.38	16.13
1.0	15.88	15.64	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.52	13.30	13.08	12.86	12.64	12.43	12.22	12.01	11.80	11.60
1.2	11.40	11.20	11.00	10.80	10.61	10.42	10.23	10.05	9.86	9.68
1.3	9.50	9.33	9.15	8.98	8.81	8.64	8.48	8.31	8.15	7.99
1.4	7.84	7.68	7.53	7.38	7.23	7.09	6.94	6.80	6.66	6.52
1.5	6.39	6.26	6.12	5.99	5.87	5.74	5.62	5.50	5.38	5.26
1.6	5.14	5.03	4.92	4.81	4.70	4.59	4.49	4.38	4.28	4.18
1.7	4.09	3.99	3.90	3.80	3.71	3.62	3.54	3.45	3.37	3.28
1.8	3.20	3.12	3.04	2.97	2.89	2.82	2.75	2.68	2.61	2.54
1.9	2.47	2.41	2.34	2.28	2.22	2.16	2.10	2.04	1.99	1.93
2.0	1.88	1.83	1.77	1.72	1.67	1.63	1.58	1.53	1.49	1.45
2.1	1.40	1.36	1.32	1.28	1.24	1.20	1.17	1.13	1.10	1.06
2.2	1.03	1.00	0.96	0.93	0.90	0.87	0.85	0.82	0.79	0.77
2.3	0.74	0.71	0.69	0.67	0.64	0.62	0.60	0.58	0.56	0.54
2.4	0.52	0.50	0.48	0.47	0.45	0.43	0.42	0.40	0.39	0.37
2.5	0.36	0.34	0.33	0.32	0.31	0.29	0.28	0.27	0.26	0.25
2.6	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.16
2.7	0.16	0.15	0.14	0.14	0.13	0.13	0.12	0.11	0.11	0.10
2.8	0.10	0.09	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.06
2.9	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04
3.0	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
3.1	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
3.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 24 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.42	48.03	47.64	47.24	46.85	46.46
0.1	46.07	45.67	45.28	44.89	44.50	44.11	43.72	43.33	42.94	42.55
0.2	42.17	41.78	41.39	41.01	40.62	40.24	39.86	39.48	39.10	38.72
0.3	38.34	37.96	37.58	37.21	36.83	36.46	36.09	35.72	35.35	34.98
0.4	34.61	34.25	33.88	33.52	33.16	32.80	32.44	32.08	31.73	31.37
0.5	31.02	30.67	30.32	29.97	29.63	29.28	28.94	28.60	28.26	27.92
0.6	27.59	27.26	26.92	26.59	26.27	25.94	25.62	25.30	24.98	24.66
0.7	24.34	24.03	23.72	23.41	23.10	22.79	22.49	22.19	21.89	21.59
0.8	21.30	21.01	20.72	20.43	20.14	19.86	19.58	19.30	19.02	18.75
0.9	18.48	18.21	17.94	17.67	17.41	17.15	16.89	16.64	16.38	16.13
1.0	15.88	15.64	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.52	13.30	13.08	12.86	12.65	12.43	12.22	12.01	11.81	11.60
1.2	11.40	11.20	11.00	10.81	10.62	10.43	10.24	10.05	9.87	9.69
1.3	9.51	9.34	9.16	8.99	8.82	8.65	8.49	8.32	8.16	8.01
1.4	7.85	7.69	7.54	7.39	7.24	7.10	6.96	6.81	6.67	6.54
1.5	6.40	6.27	6.14	6.01	5.88	5.76	5.63	5.51	5.39	5.27
1.6	5.16	5.05	4.93	4.82	4.72	4.61	4.50	4.40	4.30	4.20
1.7	4.10	4.01	3.91	3.82	3.73	3.64	3.55	3.47	3.38	3.30
1.8	3.22	3.14	3.06	2.99	2.91	2.84	2.76	2.69	2.62	2.56
1.9	2.49	2.43	2.36	2.30	2.24	2.18	2.12	2.06	2.01	1.95
2.0	1.90	1.84	1.79	1.74	1.69	1.64	1.60	1.55	1.51	1.46
2.1	1.42	1.38	1.34	1.30	1.26	1.22	1.18	1.15	1.11	1.08
2.2	1.05	1.01	0.98	0.95	0.92	0.89	0.86	0.83	0.81	0.78
2.3	0.75	0.73	0.71	0.68	0.66	0.64	0.61	0.59	0.57	0.55
2.4	0.53	0.52	0.50	0.48	0.46	0.45	0.43	0.41	0.40	0.38
2.5	0.37	0.36	0.34	0.33	0.32	0.30	0.29	0.28	0.27	0.26
2.6	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18	0.17
2.7	0.16	0.16	0.15	0.14	0.14	0.13	0.13	0.12	0.12	0.11
2.8	0.10	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07
2.9	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04
3.0	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
3.1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
3.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 25 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.42	48.03	47.64	47.24	46.85	46.46
0.1	46.06	45.67	45.28	44.89	44.50	44.11	43.72	43.33	42.94	42.55
0.2	42.16	41.78	41.39	41.00	40.62	40.24	39.85	39.47	39.09	38.71
0.3	38.33	37.95	37.58	37.20	36.83	36.45	36.08	35.71	35.34	34.97
0.4	34.60	34.24	33.87	33.51	33.15	32.79	32.43	32.07	31.72	31.36
0.5	31.01	30.66	30.31	29.96	29.62	29.27	28.93	28.59	28.25	27.92
0.6	27.58	27.25	26.92	26.59	26.26	25.93	25.61	25.29	24.97	24.65
0.7	24.33	24.02	23.71	23.40	23.09	22.79	22.48	22.18	21.89	21.59
0.8	21.29	21.00	20.71	20.42	20.14	19.86	19.57	19.30	19.02	18.74
0.9	18.47	18.20	17.94	17.67	17.41	17.15	16.89	16.63	16.38	16.13
1.0	15.88	15.63	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.52	13.30	13.08	12.86	12.65	12.44	12.22	12.02	11.81	11.61
1.2	11.41	11.21	11.01	10.82	10.62	10.43	10.25	10.06	9.88	9.70
1.3	9.52	9.34	9.17	9.00	8.83	8.66	8.50	8.33	8.17	8.01
1.4	7.86	7.70	7.55	7.40	7.26	7.11	6.97	6.83	6.69	6.55
1.5	6.41	6.28	6.15	6.02	5.89	5.77	5.65	5.53	5.41	5.29
1.6	5.17	5.06	4.95	4.84	4.73	4.62	4.52	4.42	4.32	4.22
1.7	4.12	4.02	3.93	3.84	3.75	3.66	3.57	3.48	3.40	3.32
1.8	3.24	3.16	3.08	3.00	2.93	2.85	2.78	2.71	2.64	2.57
1.9	2.51	2.44	2.38	2.32	2.25	2.19	2.14	2.08	2.02	1.97
2.0	1.91	1.86	1.81	1.76	1.71	1.66	1.61	1.57	1.52	1.48
2.1	1.44	1.39	1.35	1.31	1.28	1.24	1.20	1.16	1.13	1.09
2.2	1.06	1.03	1.00	0.96	0.93	0.91	0.88	0.85	0.82	0.79
2.3	0.77	0.74	0.72	0.70	0.67	0.65	0.63	0.61	0.59	0.57
2.4	0.55	0.53	0.51	0.49	0.47	0.46	0.44	0.42	0.41	0.39
2.5	0.38	0.37	0.35	0.34	0.33	0.31	0.30	0.29	0.28	0.27
2.6	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19	0.18
2.7	0.17	0.16	0.16	0.15	0.14	0.14	0.13	0.13	0.12	0.12
2.8	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.07
2.9	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04
3.0	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
3.1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
3.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 26 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.42	48.03	47.63	47.24	46.85	46.45
0.1	46.06	45.67	45.28	44.88	44.49	44.10	43.71	43.32	42.93	42.55
0.2	42.16	41.77	41.38	41.00	40.61	40.23	39.85	39.47	39.08	38.70
0.3	38.33	37.95	37.57	37.20	36.82	36.45	36.07	35.70	35.33	34.97
0.4	34.60	34.23	33.87	33.50	33.14	32.78	32.42	32.07	31.71	31.36
0.5	31.00	30.65	30.30	29.96	29.61	29.27	28.92	28.58	28.25	27.91
0.6	27.57	27.24	26.91	26.58	26.25	25.93	25.60	25.28	24.96	24.64
0.7	24.33	24.02	23.70	23.39	23.09	22.78	22.48	22.18	21.88	21.58
0.8	21.29	21.00	20.71	20.42	20.13	19.85	19.57	19.29	19.01	18.74
0.9	18.47	18.20	17.93	17.67	17.41	17.15	16.89	16.63	16.38	16.13
1.0	15.88	15.63	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.53	13.30	13.08	12.87	12.65	12.44	12.23	12.02	11.81	11.61
1.2	11.41	11.21	11.01	10.82	10.63	10.44	10.25	10.07	9.88	9.70
1.3	9.53	9.35	9.18	9.00	8.84	8.67	8.50	8.34	8.18	8.02
1.4	7.87	7.71	7.56	7.41	7.27	7.12	6.98	6.84	6.70	6.56
1.5	6.43	6.29	6.16	6.03	5.91	5.78	5.66	5.54	5.42	5.30
1.6	5.19	5.07	4.96	4.85	4.74	4.64	4.53	4.43	4.33	4.23
1.7	4.13	4.04	3.94	3.85	3.76	3.67	3.59	3.50	3.42	3.33
1.8	3.25	3.17	3.09	3.02	2.94	2.87	2.80	2.73	2.66	2.59
1.9	2.52	2.46	2.39	2.33	2.27	2.21	2.15	2.09	2.04	1.98
2.0	1.93	1.88	1.82	1.77	1.72	1.68	1.63	1.58	1.54	1.49
2.1	1.45	1.41	1.37	1.33	1.29	1.25	1.21	1.18	1.14	1.11
2.2	1.07	1.04	1.01	0.98	0.95	0.92	0.89	0.86	0.83	0.81
2.3	0.78	0.76	0.73	0.71	0.68	0.66	0.64	0.62	0.60	0.58
2.4	0.56	0.54	0.52	0.50	0.48	0.47	0.45	0.43	0.42	0.40
2.5	0.39	0.38	0.36	0.35	0.34	0.32	0.31	0.30	0.29	0.28
2.6	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.19
2.7	0.18	0.17	0.16	0.16	0.15	0.14	0.14	0.13	0.13	0.12
2.8	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08	0.08
2.9	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05
3.0	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
3.1	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3.2	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 27 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.42	48.03	47.63	47.24	46.85	46.45
0.1	46.06	45.67	45.27	44.88	44.49	44.10	43.71	43.32	42.93	42.54
0.2	42.15	41.77	41.38	41.00	40.61	40.23	39.84	39.46	39.08	38.70
0.3	38.32	37.94	37.57	37.19	36.82	36.44	36.07	35.70	35.33	34.96
0.4	34.59	34.23	33.86	33.50	33.14	32.78	32.42	32.06	31.70	31.35
0.5	31.00	30.65	30.30	29.95	29.60	29.26	28.92	28.58	28.24	27.90
0.6	27.57	27.23	26.90	26.57	26.25	25.92	25.60	25.28	24.96	24.64
0.7	24.32	24.01	23.70	23.39	23.08	22.78	22.47	22.17	21.87	21.58
0.8	21.28	20.99	20.70	20.42	20.13	19.85	19.57	19.29	19.01	18.74
0.9	18.47	18.20	17.93	17.67	17.40	17.14	16.89	16.63	16.38	16.13
1.0	15.88	15.63	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.53	13.31	13.09	12.87	12.65	12.44	12.23	12.02	11.82	11.61
1.2	11.41	11.21	11.02	10.82	10.63	10.44	10.26	10.07	9.89	9.71
1.3	9.53	9.36	9.18	9.01	8.84	8.68	8.51	8.35	8.19	8.03
1.4	7.88	7.72	7.57	7.42	7.27	7.13	6.99	6.85	6.71	6.57
1.5	6.44	6.30	6.17	6.04	5.92	5.79	5.67	5.55	5.43	5.31
1.6	5.20	5.08	4.97	4.86	4.76	4.65	4.55	4.44	4.34	4.24
1.7	4.15	4.05	3.96	3.87	3.78	3.69	3.60	3.51	3.43	3.35
1.8	3.27	3.19	3.11	3.03	2.96	2.88	2.81	2.74	2.67	2.60
1.9	2.54	2.47	2.41	2.35	2.28	2.22	2.17	2.11	2.05	2.00
2.0	1.94	1.89	1.84	1.79	1.74	1.69	1.64	1.60	1.55	1.51
2.1	1.47	1.42	1.38	1.34	1.30	1.26	1.23	1.19	1.16	1.12
2.2	1.09	1.05	1.02	0.99	0.96	0.93	0.90	0.87	0.85	0.82
2.3	0.79	0.77	0.74	0.72	0.70	0.67	0.65	0.63	0.61	0.59
2.4	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.43	0.41
2.5	0.40	0.38	0.37	0.36	0.34	0.33	0.32	0.31	0.30	0.28
2.6	0.27	0.26	0.25	0.24	0.23	0.22	0.22	0.21	0.20	0.19
2.7	0.18	0.18	0.17	0.16	0.16	0.15	0.14	0.14	0.13	0.13
2.8	0.12	0.12	0.11	0.11	0.10	0.10	0.09	0.09	0.08	0.08
2.9	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
3.0	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
3.1	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3.2	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 28 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.42	48.03	47.63	47.24	46.84	46.45
0.1	46.06	45.66	45.27	44.88	44.49	44.10	43.71	43.32	42.93	42.54
0.2	42.15	41.76	41.38	40.99	40.61	40.22	39.84	39.46	39.08	38.70
0.3	38.32	37.94	37.56	37.18	36.81	36.44	36.06	35.69	35.32	34.95
0.4	34.59	34.22	33.86	33.49	33.13	32.77	32.41	32.05	31.70	31.34
0.5	30.99	30.64	30.29	29.94	29.60	29.25	28.91	28.57	28.23	27.90
0.6	27.56	27.23	26.90	26.57	26.24	25.91	25.59	25.27	24.95	24.63
0.7	24.32	24.00	23.69	23.38	23.08	22.77	22.47	22.17	21.87	21.57
0.8	21.28	20.99	20.70	20.41	20.13	19.84	19.56	19.28	19.01	18.73
0.9	18.46	18.19	17.93	17.66	17.40	17.14	16.88	16.63	16.38	16.13
1.0	15.88	15.63	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.53	13.31	13.09	12.87	12.66	12.44	12.23	12.03	11.82	11.62
1.2	11.42	11.22	11.02	10.83	10.64	10.45	10.26	10.08	9.89	9.71
1.3	9.54	9.36	9.19	9.02	8.85	8.68	8.52	8.36	8.20	8.04
1.4	7.88	7.73	7.58	7.43	7.28	7.14	7.00	6.86	6.72	6.58
1.5	6.45	6.31	6.18	6.05	5.93	5.80	5.68	5.56	5.44	5.32
1.6	5.21	5.10	4.98	4.88	4.77	4.66	4.56	4.46	4.36	4.26
1.7	4.16	4.06	3.97	3.88	3.79	3.70	3.61	3.53	3.44	3.36
1.8	3.28	3.20	3.12	3.05	2.97	2.90	2.83	2.75	2.69	2.62
1.9	2.55	2.49	2.42	2.36	2.30	2.24	2.18	2.12	2.07	2.01
2.0	1.96	1.90	1.85	1.80	1.75	1.70	1.66	1.61	1.57	1.52
2.1	1.48	1.44	1.39	1.35	1.32	1.28	1.24	1.20	1.17	1.13
2.2	1.10	1.07	1.03	1.00	0.97	0.94	0.91	0.88	0.86	0.83
2.3	0.80	0.78	0.75	0.73	0.71	0.68	0.66	0.64	0.62	0.60
2.4	0.58	0.56	0.54	0.52	0.50	0.49	0.47	0.45	0.44	0.42
2.5	0.41	0.39	0.38	0.36	0.35	0.34	0.33	0.31	0.30	0.29
2.6	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.21	0.20
2.7	0.19	0.18	0.17	0.17	0.16	0.15	0.15	0.14	0.14	0.13
2.8	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.08
2.9	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.05
3.0	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03
3.1	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
3.2	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.4	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE)/ (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 29 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.61	49.21	48.82	48.42	48.03	47.63	47.24	46.84	46.45
0.1	46.06	45.66	45.27	44.88	44.49	44.10	43.70	43.31	42.93	42.54
0.2	42.15	41.76	41.37	40.99	40.60	40.22	39.84	39.45	39.07	38.69
0.3	38.31	37.93	37.56	37.18	36.81	36.43	36.06	35.69	35.32	34.95
0.4	34.58	34.22	33.85	33.49	33.13	32.77	32.41	32.05	31.69	31.34
0.5	30.99	30.64	30.29	29.94	29.59	29.25	28.91	28.57	28.23	27.89
0.6	27.56	27.22	26.89	26.56	26.23	25.91	25.59	25.26	24.95	24.63
0.7	24.31	24.00	23.69	23.38	23.07	22.77	22.46	22.16	21.87	21.57
0.8	21.28	20.98	20.69	20.41	20.12	19.84	19.56	19.28	19.01	18.73
0.9	18.46	18.19	17.93	17.66	17.40	17.14	16.88	16.63	16.37	16.12
1.0	15.88	15.63	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.53	13.31	13.09	12.87	12.66	12.44	12.24	12.03	11.82	11.62
1.2	11.42	11.22	11.03	10.83	10.64	10.45	10.27	10.08	9.90	9.72
1.3	9.54	9.37	9.19	9.02	8.85	8.69	8.52	8.36	8.20	8.05
1.4	7.89	7.74	7.59	7.44	7.29	7.15	7.00	6.86	6.73	6.59
1.5	6.45	6.32	6.19	6.06	5.94	5.81	5.69	5.57	5.45	5.33
1.6	5.22	5.11	5.00	4.89	4.78	4.67	4.57	4.47	4.37	4.27
1.7	4.17	4.08	3.98	3.89	3.80	3.71	3.62	3.54	3.45	3.37
1.8	3.29	3.21	3.13	3.06	2.98	2.91	2.84	2.77	2.70	2.63
1.9	2.56	2.50	2.43	2.37	2.31	2.25	2.19	2.13	2.08	2.02
2.0	1.97	1.92	1.86	1.81	1.76	1.72	1.67	1.62	1.58	1.53
2.1	1.49	1.45	1.41	1.37	1.33	1.29	1.25	1.21	1.18	1.14
2.2	1.11	1.08	1.04	1.01	0.98	0.95	0.92	0.89	0.87	0.84
2.3	0.81	0.79	0.76	0.74	0.71	0.69	0.67	0.65	0.63	0.61
2.4	0.59	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.43
2.5	0.41	0.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30
2.6	0.29	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21	0.20
2.7	0.19	0.19	0.18	0.17	0.17	0.16	0.15	0.15	0.14	0.13
2.8	0.13	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.09	0.09
2.9	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.06
3.0	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03
3.1	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
3.2	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.4	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT DEFECTIVE ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 30 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.60	49.21	48.81	48.42	48.02	47.63	47.24	46.84	46.45
0.1	46.05	45.66	45.27	44.88	44.48	44.09	43.70	43.31	42.92	42.53
0.2	42.15	41.76	41.37	40.99	40.60	40.22	39.83	39.45	39.07	38.69
0.3	38.31	37.93	37.55	37.18	36.80	36.43	36.05	35.68	35.31	34.94
0.4	34.58	34.21	33.85	33.48	33.12	32.76	32.40	32.04	31.69	31.33
0.5	30.98	30.63	30.28	29.93	29.59	29.24	28.90	28.56	28.22	27.89
0.6	27.55	27.22	26.89	26.56	26.23	25.90	25.58	25.26	24.94	24.62
0.7	24.31	23.99	23.68	23.37	23.07	22.76	22.46	22.16	21.86	21.57
0.8	21.27	20.98	20.69	20.40	20.12	19.84	19.56	19.28	19.00	18.73
0.9	18.46	18.19	17.92	17.66	17.40	17.14	16.88	16.63	16.37	16.12
1.0	15.88	15.63	15.39	15.15	14.91	14.67	14.44	14.21	13.98	13.75
1.1	13.53	13.31	13.09	12.87	12.66	12.45	12.24	12.03	11.82	11.62
1.2	11.42	11.22	11.03	10.84	10.64	10.46	10.27	10.09	9.90	9.72
1.3	9.55	9.37	9.20	9.03	8.86	8.69	8.53	8.37	8.21	8.05
1.4	7.90	7.74	7.59	7.44	7.30	7.15	7.01	6.87	6.73	6.60
1.5	6.46	6.33	6.20	6.07	5.95	5.82	5.70	5.58	5.46	5.34
1.6	5.23	5.12	5.01	4.90	4.79	4.68	4.58	4.48	4.38	4.28
1.7	4.18	4.09	3.99	3.90	3.81	3.72	3.63	3.55	3.47	3.38
1.8	3.30	3.22	3.15	3.07	2.99	2.92	2.85	2.78	2.71	2.64
1.9	2.57	2.51	2.45	2.38	2.32	2.26	2.20	2.14	2.09	2.03
2.0	1.98	1.93	1.87	1.82	1.77	1.73	1.68	1.63	1.59	1.54
2.1	1.50	1.46	1.42	1.38	1.34	1.30	1.26	1.22	1.19	1.15
2.2	1.12	1.09	1.05	1.02	0.99	0.96	0.93	0.90	0.88	0.85
2.3	0.82	0.80	0.77	0.75	0.72	0.70	0.68	0.66	0.63	0.61
2.4	0.59	0.57	0.56	0.54	0.52	0.50	0.48	0.47	0.45	0.44
2.5	0.42	0.41	0.39	0.38	0.37	0.35	0.34	0.33	0.32	0.30
2.6	0.29	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.22	0.21
2.7	0.20	0.19	0.18	0.18	0.17	0.16	0.16	0.15	0.14	0.14
2.8	0.13	0.13	0.12	0.12	0.11	0.11	0.10	0.10	0.09	0.09
2.9	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06
3.0	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
3.1	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
3.2	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
3.3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3.4	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT DEFECTIVE CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 3 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.28	50.55	50.83	51.10	51.38	51.65	51.93	52.21	52.48
0.1	52.76	53.04	53.31	53.59	53.87	54.15	54.42	54.70	54.98	55.26
0.2	55.54	55.82	56.10	56.38	56.66	56.95	57.23	57.51	57.80	58.08
0.3	58.37	58.65	58.94	59.23	59.51	59.80	60.09	60.38	60.67	60.97
0.4	61.26	61.55	61.85	62.15	62.44	62.74	63.04	63.34	63.65	63.95
0.5	64.25	64.56	64.87	65.18	65.49	65.80	66.12	66.43	66.75	67.07
0.6	67.39	67.72	68.04	68.37	68.70	69.03	69.37	69.70	70.04	70.39
0.7	70.73	71.08	71.43	71.78	72.14	72.50	72.87	73.24	73.61	73.98
0.8	74.36	74.75	75.14	75.53	75.93	76.33	76.74	77.16	77.58	78.01
0.9	78.45	78.89	79.34	79.81	80.27	80.75	81.25	81.75	82.26	82.79
1.0	83.33	83.89	84.47	85.07	85.69	86.34	87.02	87.73	88.49	89.29
1.1	90.16	91.11	92.18	93.40	94.92	97.13	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 4 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.33	50.67	51.00	51.33	51.67	52.00	52.33	52.67	53.00
0.1	53.33	53.67	54.00	54.33	54.67	55.00	55.33	55.67	56.00	56.33
0.2	56.67	57.00	57.33	57.67	58.00	58.33	58.67	59.00	59.33	59.67
0.3	60.00	60.33	60.67	61.00	61.33	61.67	62.00	62.33	62.67	63.00
0.4	63.33	63.67	64.00	64.33	64.67	65.00	65.33	65.67	66.00	66.33
0.5	66.67	67.00	67.33	67.67	68.00	68.33	68.67	69.00	69.33	69.67
0.6	70.00	70.33	70.67	71.00	71.33	71.67	72.00	72.33	72.67	73.00
0.7	73.33	73.67	74.00	74.33	74.67	75.00	75.33	75.67	76.00	76.33
0.8	76.67	77.00	77.33	77.67	78.00	78.33	78.67	79.00	79.33	79.67
0.9	80.00	80.33	80.67	81.00	81.33	81.67	82.00	82.33	82.67	83.00
1.0	83.33	83.67	84.00	84.33	84.67	85.00	85.33	85.67	86.00	86.33
1.1	86.67	87.00	87.33	87.67	88.00	88.33	88.67	89.00	89.33	89.67
1.2	90.00	90.33	90.67	91.00	91.33	91.67	92.00	92.33	92.67	93.00
1.3	93.33	93.67	94.00	94.33	94.67	95.00	95.33	95.67	96.00	96.33
1.4	96.67	97.00	97.33	97.67	98.00	98.33	98.67	99.00	99.33	99.67
1.5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 5 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.36	50.71	51.07	51.42	51.78	52.13	52.49	52.85	53.20
0.1	53.56	53.91	54.27	54.62	54.98	55.33	55.69	56.04	56.39	56.75
0.2	57.10	57.46	57.81	58.16	58.52	58.87	59.22	59.57	59.92	60.28
0.3	60.63	60.98	61.33	61.68	62.03	62.38	62.72	63.07	63.42	63.77
0.4	64.12	64.46	64.81	65.15	65.50	65.84	66.19	66.53	66.87	67.22
0.5	67.56	67.90	68.24	68.58	68.92	69.26	69.60	69.94	70.27	70.61
0.6	70.95	71.28	71.61	71.95	72.28	72.61	72.94	73.27	73.60	73.93
0.7	74.26	74.59	74.91	75.24	75.56	75.89	76.21	76.53	76.85	77.17
0.8	77.49	77.81	78.13	78.44	78.76	79.07	79.38	79.69	80.00	80.31
0.9	80.62	80.93	81.23	81.54	81.84	82.14	82.45	82.74	83.04	83.34
1.0	83.64	83.93	84.22	84.52	84.81	85.09	85.38	85.67	85.95	86.24
1.1	86.52	86.80	87.07	87.35	87.63	87.90	88.17	88.44	88.71	88.98
1.2	89.24	89.50	89.77	90.03	90.28	90.54	90.79	91.04	91.29	91.54
1.3	91.79	92.03	92.27	92.51	92.75	92.98	93.21	93.44	93.67	93.90
1.4	94.12	94.34	94.56	94.77	94.98	95.19	95.40	95.61	95.81	96.01
1.5	96.20	96.39	96.58	96.77	96.95	97.13	97.31	97.48	97.65	97.81
1.6	97.97	98.13	98.28	98.43	98.58	98.72	98.85	98.98	99.11	99.23
1.7	99.34	99.45	99.55	99.64	99.73	99.81	99.88	99.94	99.98	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 6 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.37	50.73	51.10	51.47	51.84	52.20	52.57	52.94	53.30
0.1	53.67	54.04	54.40	54.77	55.14	55.50	55.87	56.23	56.60	56.96
0.2	57.32	57.69	58.05	58.41	58.78	59.14	59.50	59.86	60.22	60.58
0.3	60.94	61.30	61.66	62.02	62.38	62.73	63.09	63.45	63.80	64.16
0.4	64.51	64.86	65.21	65.57	65.92	66.27	66.62	66.96	67.31	67.66
0.5	68.00	68.35	68.69	69.04	69.38	69.72	70.06	70.40	70.74	71.07
0.6	71.41	71.75	72.08	72.41	72.74	73.08	73.40	73.73	74.06	74.39
0.7	74.71	75.04	75.36	75.68	76.00	76.32	76.63	76.95	77.26	77.58
0.8	77.89	78.20	78.51	78.82	79.12	79.43	79.73	80.03	80.33	80.63
0.9	80.93	81.22	81.51	81.81	82.10	82.39	82.67	82.96	83.24	83.52
1.0	83.80	84.08	84.36	84.63	84.91	85.18	85.45	85.71	85.98	86.24
1.1	86.50	86.76	87.02	87.28	87.53	87.78	88.03	88.28	88.53	88.77
1.2	89.01	89.25	89.49	89.72	89.96	90.19	90.42	90.64	90.87	91.09
1.3	91.31	91.52	91.74	91.95	92.16	92.37	92.58	92.78	92.98	93.18
1.4	93.37	93.57	93.76	93.95	94.13	94.32	94.50	94.67	94.85	95.02
1.5	95.19	95.36	95.53	95.69	95.85	96.00	96.16	96.31	96.46	96.60
1.6	96.75	96.89	97.03	97.16	97.29	97.42	97.55	97.67	97.79	97.91
1.7	98.02	98.13	98.24	98.34	98.45	98.55	98.64	98.73	98.82	98.91
1.8	98.99	99.07	99.15	99.22	99.29	99.36	99.43	99.49	99.54	99.60
1.9	99.65	99.70	99.74	99.78	99.82	99.85	99.88	99.91	99.93	99.95
2.0	99.97	99.98	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 7 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.37	50.75	51.12	51.50	51.87	52.24	52.62	52.99	53.37
0.1	53.74	54.11	54.49	54.86	55.23	55.60	55.97	56.35	56.72	57.09
0.2	57.46	57.83	58.20	58.56	58.93	59.30	59.67	60.03	60.40	60.77
0.3	61.13	61.50	61.86	62.22	62.58	62.94	63.31	63.67	64.02	64.38
0.4	64.74	65.10	65.45	65.81	66.16	66.51	66.87	67.22	67.57	67.92
0.5	68.26	68.61	68.96	69.30	69.64	69.99	70.33	70.67	71.01	71.34
0.6	71.68	72.02	72.35	72.68	73.01	73.34	73.67	74.00	74.32	74.65
0.7	74.97	75.29	75.61	75.93	76.25	76.56	76.88	77.19	77.50	77.81
0.8	78.12	78.42	78.73	79.03	79.33	79.63	79.93	80.22	80.52	80.81
0.9	81.10	81.39	81.67	81.96	82.24	82.52	82.80	83.08	83.35	83.63
1.0	83.90	84.17	84.44	84.70	84.97	85.23	85.49	85.74	86.00	86.25
1.1	86.51	86.75	87.00	87.25	87.49	87.73	87.97	88.21	88.44	88.67
1.2	88.90	89.13	89.35	89.58	89.80	90.02	90.23	90.45	90.66	90.87
1.3	91.07	91.28	91.48	91.68	91.88	92.08	92.27	92.46	92.65	92.83
1.4	93.02	93.20	93.38	93.55	93.73	93.90	94.07	94.23	94.40	94.56
1.5	94.72	94.87	95.03	95.18	95.33	95.48	95.62	95.76	95.90	96.04
1.6	96.17	96.31	96.43	96.56	96.69	96.81	96.93	97.05	97.16	97.27
1.7	97.38	97.49	97.59	97.70	97.80	97.89	97.99	98.08	98.17	98.26
1.8	98.35	98.43	98.51	98.59	98.66	98.74	98.81	98.88	98.94	99.01
1.9	99.07	99.13	99.19	99.24	99.30	99.35	99.40	99.44	99.49	99.53
2.0	99.57	99.61	99.64	99.68	99.71	99.74	99.77	99.79	99.82	99.84
2.1	99.86	99.88	99.90	99.92	99.93	99.94	99.95	99.96	99.97	99.98
2.2	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 8 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.38	50.76	51.14	51.51	51.89	52.27	52.65	53.03	53.41
0.1	53.78	54.16	54.54	54.92	55.29	55.67	56.04	56.42	56.79	57.17
0.2	57.54	57.92	58.29	58.66	59.03	59.41	59.78	60.15	60.52	60.89
0.3	61.25	61.62	61.99	62.35	62.72	63.08	63.45	63.81	64.17	64.53
0.4	64.89	65.25	65.61	65.96	66.32	66.67	67.03	67.38	67.73	68.08
0.5	68.43	68.78	69.13	69.47	69.82	70.16	70.50	70.84	71.18	71.52
0.6	71.85	72.19	72.52	72.85	73.18	73.51	73.84	74.17	74.49	74.81
0.7	75.14	75.46	75.77	76.09	76.41	76.72	77.03	77.34	77.65	77.96
0.8	78.26	78.56	78.86	79.16	79.46	79.76	80.05	80.34	80.63	80.92
0.9	81.21	81.49	81.77	82.05	82.33	82.61	82.88	83.15	83.43	83.69
1.0	83.96	84.22	84.49	84.75	85.00	85.26	85.51	85.76	86.01	86.26
1.1	86.51	86.75	86.99	87.23	87.46	87.70	87.93	88.16	88.39	88.61
1.2	88.83	89.06	89.27	89.49	89.70	89.91	90.12	90.33	90.53	90.74
1.3	90.94	91.13	91.33	91.52	91.71	91.90	92.09	92.27	92.45	92.63
1.4	92.81	92.98	93.15	93.32	93.49	93.65	93.81	93.97	94.13	94.29
1.5	94.44	94.59	94.74	94.88	95.03	95.17	95.31	95.44	95.58	95.71
1.6	95.84	95.97	96.09	96.21	96.33	96.45	96.57	96.68	96.79	96.90
1.7	97.01	97.11	97.21	97.31	97.41	97.51	97.60	97.69	97.78	97.87
1.8	97.96	98.04	98.12	98.20	98.28	98.35	98.42	98.49	98.56	98.63
1.9	98.69	98.76	98.82	98.88	98.93	98.99	99.04	99.09	99.14	99.19
2.0	99.24	99.28	99.33	99.37	99.41	99.45	99.48	99.52	99.55	99.58
2.1	99.61	99.64	99.67	99.70	99.72	99.74	99.77	99.79	99.81	99.83
2.2	99.84	99.86	99.87	99.89	99.90	99.91	99.92	99.93	99.94	99.95
2.3	99.96	99.96	99.97	99.98	99.98	99.98	99.99	99.99	99.99	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 9 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.38	50.76	51.15	51.53	51.91	52.29	52.67	53.05	53.43
0.1	53.82	54.20	54.58	54.96	55.34	55.71	56.09	56.47	56.85	57.23
0.2	57.60	57.98	58.36	58.73	59.11	59.48	59.85	60.23	60.60	60.97
0.3	61.34	61.71	62.08	62.45	62.81	63.18	63.54	63.91	64.27	64.63
0.4	65.00	65.36	65.71	66.07	66.43	66.79	67.14	67.49	67.85	68.20
0.5	68.55	68.90	69.24	69.59	69.93	70.28	70.62	70.96	71.30	71.64
0.6	71.97	72.31	72.64	72.97	73.30	73.63	73.96	74.28	74.61	74.93
0.7	75.25	75.57	75.89	76.20	76.51	76.83	77.14	77.44	77.75	78.06
0.8	78.36	78.66	78.96	79.25	79.55	79.84	80.13	80.42	80.71	81.00
0.9	81.28	81.56	81.84	82.12	82.39	82.67	82.94	83.21	83.47	83.74
1.0	84.00	84.26	84.52	84.77	85.03	85.28	85.53	85.78	86.02	86.27
1.1	86.51	86.74	86.98	87.21	87.45	87.68	87.90	88.13	88.35	88.57
1.2	88.79	89.00	89.22	89.43	89.64	89.85	90.05	90.25	90.45	90.65
1.3	90.84	91.04	91.23	91.41	91.60	91.78	91.96	92.14	92.32	92.49
1.4	92.67	92.83	93.00	93.17	93.33	93.49	93.65	93.80	93.96	94.11
1.5	94.26	94.40	94.55	94.69	94.83	94.97	95.10	95.23	95.36	95.49
1.6	95.62	95.74	95.86	95.98	96.10	96.22	96.33	96.44	96.55	96.66
1.7	96.76	96.86	96.97	97.06	97.16	97.25	97.35	97.44	97.53	97.61
1.8	97.70	97.78	97.86	97.94	98.02	98.09	98.16	98.24	98.30	98.37
1.9	98.44	98.50	98.56	98.63	98.68	98.74	98.80	98.85	98.90	98.95
2.0	99.00	99.05	99.10	99.14	99.18	99.23	99.27	99.30	99.34	99.38
2.1	99.41	99.45	99.48	99.51	99.54	99.57	99.59	99.62	99.64	99.67
2.2	99.69	99.71	99.73	99.75	99.77	99.79	99.80	99.82	99.83	99.85
2.3	99.86	99.87	99.89	99.90	99.91	99.92	99.92	99.93	99.94	99.95
2.4	99.95	99.96	99.96	99.97	99.97	99.98	99.98	99.98	99.99	99.99
2.5	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 10 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.38	50.77	51.15	51.54	51.92	52.30	52.69	53.07	53.46
0.1	53.84	54.22	54.60	54.99	55.37	55.75	56.13	56.51	56.89	57.27
0.2	57.65	58.03	58.40	58.78	59.16	59.53	59.91	60.28	60.66	61.03
0.3	61.40	61.77	62.14	62.51	62.88	63.25	63.62	63.98	64.35	64.71
0.4	65.07	65.43	65.79	66.15	66.51	66.87	67.22	67.58	67.93	68.28
0.5	68.63	68.98	69.33	69.68	70.02	70.36	70.71	71.05	71.39	71.72
0.6	72.06	72.40	72.73	73.06	73.39	73.72	74.04	74.37	74.69	75.01
0.7	75.33	75.65	75.97	76.28	76.59	76.90	77.21	77.52	77.82	78.13
0.8	78.43	78.73	79.02	79.32	79.61	79.90	80.19	80.48	80.77	81.05
0.9	81.33	81.61	81.89	82.16	82.44	82.71	82.97	83.24	83.51	83.77
1.0	84.03	84.28	84.54	84.79	85.04	85.29	85.54	85.78	86.03	86.27
1.1	86.50	86.74	86.97	87.20	87.43	87.66	87.88	88.10	88.32	88.54
1.2	88.76	88.97	89.18	89.39	89.59	89.79	90.00	90.19	90.39	90.58
1.3	90.78	90.97	91.15	91.34	91.52	91.70	91.88	92.05	92.23	92.40
1.4	92.56	92.73	92.90	93.06	93.22	93.37	93.53	93.68	93.83	93.98
1.5	94.13	94.27	94.41	94.55	94.69	94.82	94.95	95.08	95.21	95.34
1.6	95.46	95.59	95.70	95.82	95.94	96.05	96.16	96.27	96.38	96.48
1.7	96.59	96.69	96.79	96.89	96.98	97.07	97.17	97.26	97.34	97.43
1.8	97.51	97.60	97.68	97.75	97.83	97.91	97.98	98.05	98.12	98.19
1.9	98.25	98.32	98.38	98.44	98.50	98.56	98.62	98.67	98.73	98.78
2.0	98.83	98.88	98.93	98.97	99.02	99.06	99.10	99.14	99.18	99.22
2.1	99.26	99.29	99.33	99.36	99.39	99.42	99.45	99.48	99.51	99.54
2.2	99.56	99.59	99.61	99.63	99.66	99.68	99.70	99.71	99.73	99.75
2.3	99.77	99.78	99.80	99.81	99.82	99.84	99.85	99.86	99.87	99.88
2.4	99.89	99.90	99.91	99.92	99.92	99.93	99.94	99.94	99.95	99.95
2.5	99.96	99.96	99.97	99.97	99.97	99.98	99.98	99.98	99.99	99.99
2.6	99.99	99.99	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 11 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.77	51.16	51.54	51.93	52.32	52.70	53.09	53.47
0.1	53.86	54.24	54.62	55.01	55.39	55.77	56.16	56.54	56.92	57.30
0.2	57.68	58.06	58.44	58.82	59.20	59.58	59.95	60.33	60.70	61.08
0.3	61.45	61.82	62.19	62.56	62.93	63.30	63.67	64.04	64.40	64.77
0.4	65.13	65.49	65.85	66.21	66.57	66.93	67.29	67.64	67.99	68.35
0.5	68.70	69.05	69.40	69.74	70.09	70.43	70.77	71.11	71.45	71.79
0.6	72.13	72.46	72.79	73.12	73.45	73.78	74.11	74.43	74.75	75.08
0.7	75.39	75.71	76.03	76.34	76.65	76.96	77.27	77.57	77.88	78.18
0.8	78.48	78.78	79.07	79.37	79.66	79.95	80.24	80.52	80.81	81.09
0.9	81.37	81.65	81.92	82.20	82.47	82.74	83.00	83.27	83.53	83.79
1.0	84.05	84.30	84.56	84.81	85.06	85.30	85.55	85.79	86.03	86.27
1.1	86.50	86.74	86.97	87.19	87.42	87.64	87.87	88.09	88.30	88.52
1.2	88.73	88.94	89.15	89.35	89.56	89.76	89.95	90.15	90.34	90.54
1.3	90.72	90.91	91.10	91.28	91.46	91.64	91.81	91.98	92.15	92.32
1.4	92.49	92.65	92.81	92.97	93.13	93.29	93.44	93.59	93.74	93.88
1.5	94.03	94.17	94.31	94.45	94.58	94.71	94.84	94.97	95.10	95.22
1.6	95.35	95.47	95.59	95.70	95.82	95.93	96.04	96.15	96.25	96.36
1.7	96.46	96.56	96.66	96.75	96.85	96.94	97.03	97.12	97.21	97.29
1.8	97.38	97.46	97.54	97.62	97.69	97.77	97.84	97.91	97.98	98.05
1.9	98.12	98.18	98.24	98.31	98.37	98.42	98.48	98.54	98.59	98.64
2.0	98.70	98.75	98.79	98.84	98.89	98.93	98.98	99.02	99.06	99.10
2.1	99.14	99.17	99.21	99.25	99.28	99.31	99.34	99.37	99.40	99.43
2.2	99.46	99.49	99.51	99.54	99.56	99.58	99.60	99.63	99.65	99.67
2.3	99.68	99.70	99.72	99.74	99.75	99.77	99.78	99.79	99.81	99.82
2.4	99.83	99.84	99.85	99.86	99.87	99.88	99.89	99.90	99.91	99.91
2.5	99.92	99.93	99.93	99.94	99.94	99.95	99.95	99.96	99.96	99.96
2.6	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.99	99.99	99.99
2.7	99.99	99.99	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 12 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.77	51.16	51.55	51.94	52.32	52.71	53.10	53.48
0.1	53.87	54.26	54.64	55.03	55.41	55.80	56.18	56.56	56.95	57.33
0.2	57.71	58.09	58.47	58.85	59.23	59.61	59.99	60.36	60.74	61.11
0.3	61.49	61.86	62.23	62.61	62.98	63.35	63.71	64.08	64.45	64.81
0.4	65.18	65.54	65.90	66.26	66.62	66.98	67.34	67.69	68.04	68.40
0.5	68.75	69.10	69.45	69.79	70.14	70.48	70.82	71.17	71.50	71.84
0.6	72.18	72.51	72.84	73.18	73.50	73.83	74.16	74.48	74.80	75.12
0.7	75.44	75.76	76.07	76.39	76.70	77.01	77.31	77.62	77.92	78.22
0.8	78.52	78.82	79.11	79.41	79.70	79.99	80.27	80.56	80.84	81.12
0.9	81.40	81.68	81.95	82.22	82.49	82.76	83.02	83.29	83.55	83.81
1.0	84.06	84.32	84.57	84.82	85.06	85.31	85.55	85.79	86.03	86.27
1.1	86.50	86.73	86.96	87.19	87.41	87.63	87.85	88.07	88.29	88.50
1.2	88.71	88.92	89.12	89.33	89.53	89.73	89.92	90.12	90.31	90.50
1.3	90.68	90.87	91.05	91.23	91.41	91.59	91.76	91.93	92.10	92.27
1.4	92.43	92.59	92.75	92.91	93.07	93.22	93.37	93.52	93.66	93.81
1.5	93.95	94.09	94.23	94.36	94.50	94.63	94.76	94.89	95.01	95.14
1.6	95.26	95.38	95.49	95.61	95.72	95.83	95.94	96.05	96.15	96.26
1.7	96.36	96.46	96.55	96.65	96.74	96.84	96.93	97.01	97.10	97.19
1.8	97.27	97.35	97.43	97.51	97.58	97.66	97.73	97.80	97.87	97.94
1.9	98.01	98.07	98.14	98.20	98.26	98.32	98.38	98.43	98.49	98.54
2.0	98.59	98.64	98.69	98.74	98.79	98.83	98.88	98.92	98.96	99.00
2.1	99.04	99.08	99.12	99.15	99.19	99.22	99.25	99.29	99.32	99.35
2.2	99.37	99.40	99.43	99.46	99.48	99.51	99.53	99.55	99.57	99.59
2.3	99.61	99.63	99.65	99.67	99.69	99.70	99.72	99.73	99.75	99.76
2.4	99.78	99.79	99.80	99.81	99.82	99.84	99.85	99.86	99.86	99.87
2.5	99.88	99.89	99.90	99.90	99.91	99.92	99.92	99.93	99.93	99.94
2.6	99.94	99.95	99.95	99.96	99.96	99.96	99.97	99.97	99.97	99.97
2.7	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99	99.99
2.8	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 13 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.78	51.17	51.55	51.94	52.33	52.72	53.11	53.49
0.1	53.88	54.27	54.65	55.04	55.43	55.81	56.20	56.58	56.96	57.35
0.2	57.73	58.11	58.49	58.87	59.25	59.63	60.01	60.39	60.77	61.14
0.3	61.52	61.89	62.27	62.64	63.01	63.38	63.75	64.12	64.48	64.85
0.4	65.21	65.58	65.94	66.30	66.66	67.02	67.37	67.73	68.08	68.44
0.5	68.79	69.14	69.49	69.83	70.18	70.52	70.87	71.21	71.55	71.88
0.6	72.22	72.55	72.89	73.22	73.55	73.87	74.20	74.52	74.84	75.16
0.7	75.48	75.80	76.11	76.42	76.73	77.04	77.35	77.65	77.96	78.26
0.8	78.55	78.85	79.14	79.44	79.73	80.01	80.30	80.58	80.87	81.15
0.9	81.42	81.70	81.97	82.24	82.51	82.78	83.04	83.30	83.56	83.82
1.0	84.07	84.33	84.58	84.82	85.07	85.31	85.56	85.79	86.03	86.27
1.1	86.50	86.73	86.95	87.18	87.40	87.62	87.84	88.06	88.27	88.48
1.2	88.69	88.90	89.10	89.30	89.50	89.70	89.90	90.09	90.28	90.47
1.3	90.65	90.83	91.02	91.19	91.37	91.55	91.72	91.89	92.05	92.22
1.4	92.38	92.54	92.70	92.86	93.01	93.16	93.31	93.46	93.61	93.75
1.5	93.89	94.03	94.17	94.30	94.43	94.56	94.69	94.82	94.94	95.06
1.6	95.18	95.30	95.42	95.53	95.64	95.75	95.86	95.97	96.07	96.18
1.7	96.28	96.38	96.47	96.57	96.66	96.75	96.84	96.93	97.02	97.10
1.8	97.18	97.26	97.34	97.42	97.50	97.57	97.65	97.72	97.79	97.85
1.9	97.92	97.99	98.05	98.11	98.17	98.23	98.29	98.35	98.40	98.46
2.0	98.51	98.56	98.61	98.66	98.70	98.75	98.79	98.84	98.88	98.92
2.1	98.96	99.00	99.04	99.08	99.11	99.15	99.18	99.21	99.24	99.28
2.2	99.31	99.33	99.36	99.39	99.42	99.44	99.47	99.49	99.51	99.53
2.3	99.55	99.58	99.60	99.61	99.63	99.65	99.67	99.68	99.70	99.71
2.4	99.73	99.74	99.76	99.77	99.78	99.79	99.81	99.82	99.83	99.84
2.5	99.85	99.86	99.86	99.87	99.88	99.89	99.89	99.90	99.91	99.91
2.6	99.92	99.92	99.93	99.93	99.94	99.94	99.95	99.95	99.96	99.96
2.7	99.96	99.96	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98
2.8	99.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
2.9	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE | SAMPLE SIZE 14 | STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.78	51.17	51.56	51.95	52.34	52.73	53.11	53.50
0.1	53.89	54.28	54.67	55.05	55.44	55.83	56.21	56.60	56.98	57.37
0.2	57.75	58.13	58.51	58.89	59.28	59.66	60.03	60.41	60.79	61.17
0.3	61.54	61.92	62.29	62.66	63.04	63.41	63.78	64.15	64.51	64.88
0.4	65.24	65.61	65.97	66.33	66.69	67.05	67.41	67.76	68.12	68.47
0.5	68.82	69.17	69.52	69.87	70.21	70.56	70.90	71.24	71.58	71.92
0.6	72.25	72.59	72.92	73.25	73.58	73.91	74.23	74.55	74.88	75.19
0.7	75.51	75.83	76.14	76.45	76.76	77.07	77.38	77.68	77.98	78.28
0.8	78.58	78.88	79.17	79.46	79.75	80.04	80.32	80.61	80.89	81.16
0.9	81.44	81.72	81.99	82.26	82.52	82.79	83.05	83.31	83.57	83.83
1.0	84.08	84.33	84.58	84.83	85.08	85.32	85.56	85.80	86.03	86.26
1.1	86.50	86.72	86.95	87.17	87.40	87.61	87.83	88.05	88.26	88.47
1.2	88.68	88.88	89.08	89.28	89.48	89.68	89.87	90.06	90.25	90.44
1.3	90.62	90.81	90.99	91.16	91.34	91.51	91.68	91.85	92.02	92.18
1.4	92.34	92.50	92.66	92.82	92.97	93.12	93.27	93.41	93.56	93.70
1.5	93.84	93.98	94.11	94.25	94.38	94.51	94.64	94.76	94.88	95.01
1.6	95.12	95.24	95.36	95.47	95.58	95.69	95.80	95.91	96.01	96.11
1.7	96.21	96.31	96.41	96.50	96.59	96.68	96.77	96.86	96.95	97.03
1.8	97.11	97.19	97.27	97.35	97.43	97.50	97.57	97.65	97.72	97.78
1.9	97.85	97.92	97.98	98.04	98.10	98.16	98.22	98.28	98.33	98.39
2.0	98.44	98.49	98.54	98.59	98.64	98.68	98.73	98.77	98.82	98.86
2.1	98.90	98.94	98.98	99.01	99.05	99.08	99.12	99.15	99.18	99.22
2.2	99.25	99.28	99.31	99.33	99.36	99.39	99.41	99.44	99.46	99.48
2.3	99.50	99.53	99.55	99.57	99.59	99.60	99.62	99.64	99.66	99.67
2.4	99.69	99.70	99.72	99.73	99.74	99.76	99.77	99.78	99.79	99.80
2.5	99.81	99.82	99.83	99.84	99.85	99.86	99.87	99.88	99.88	99.89
2.6	99.90	99.90	99.91	99.91	99.92	99.92	99.93	99.93	99.94	99.94
2.7	99.95	99.95	99.95	99.96	99.96	99.96	99.97	99.97	99.97	99.97
2.8	99.97	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99
2.9	99.99	99.99	99.99	99.99	99.99	99.99	99.99	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 15 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.78	51.17	51.56	51.95	52.34	52.73	53.12	53.51
0.1	53.90	54.29	54.67	55.06	55.45	55.84	56.22	56.61	56.99	57.38
0.2	57.76	58.15	58.53	58.91	59.29	59.67	60.05	60.43	60.81	61.19
0.3	61.56	61.94	62.31	62.69	63.06	63.43	63.80	64.17	64.54	64.90
0.4	65.27	65.63	66.00	66.36	66.72	67.08	67.43	67.79	68.15	68.50
0.5	68.85	69.20	69.55	69.90	70.24	70.59	70.93	71.27	71.61	71.95
0.6	72.28	72.61	72.95	73.28	73.61	73.93	74.26	74.58	74.90	75.22
0.7	75.54	75.85	76.17	76.48	76.79	77.10	77.40	77.70	78.01	78.30
0.8	78.60	78.90	79.19	79.48	79.77	80.06	80.34	80.62	80.90	81.18
0.9	81.46	81.73	82.00	82.27	82.54	82.80	83.06	83.32	83.58	83.84
1.0	84.09	84.34	84.59	84.83	85.08	85.32	85.56	85.80	86.03	86.26
1.1	86.49	86.72	86.95	87.17	87.39	87.61	87.82	88.04	88.25	88.46
1.2	88.66	88.87	89.07	89.27	89.47	89.66	89.85	90.04	90.23	90.42
1.3	90.60	90.78	90.96	91.14	91.31	91.48	91.65	91.82	91.99	92.15
1.4	92.31	92.47	92.63	92.78	92.93	93.08	93.23	93.37	93.52	93.66
1.5	93.80	93.94	94.07	94.20	94.33	94.46	94.59	94.71	94.84	94.96
1.6	95.08	95.19	95.31	95.42	95.53	95.64	95.75	95.85	95.95	96.06
1.7	96.16	96.25	96.35	96.44	96.54	96.63	96.72	96.80	96.89	96.97
1.8	97.06	97.14	97.21	97.29	97.37	97.44	97.51	97.59	97.66	97.72
1.9	97.79	97.86	97.92	97.98	98.04	98.10	98.16	98.22	98.27	98.33
2.0	98.38	98.43	98.48	98.53	98.58	98.63	98.67	98.72	98.76	98.80
2.1	98.84	98.88	98.92	98.96	99.00	99.03	99.07	99.10	99.13	99.17
2.2	99.20	99.23	99.26	99.29	99.31	99.34	99.37	99.39	99.42	99.44
2.3	99.46	99.48	99.51	99.53	99.55	99.57	99.58	99.60	99.62	99.64
2.4	99.65	99.67	99.68	99.70	99.71	99.73	99.74	99.75	99.76	99.77
2.5	99.79	99.80	99.81	99.82	99.83	99.83	99.84	99.85	99.86	99.87
2.6	99.87	99.88	99.89	99.89	99.90	99.91	99.91	99.92	99.92	99.93
2.7	99.93	99.94	99.94	99.94	99.95	99.95	99.95	99.96	99.96	99.96
2.8	99.97	99.97	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98
2.9	99.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.0	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 16 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.78	51.17	51.56	51.95	52.34	52.74	53.13	53.52
0.1	53.90	54.29	54.68	55.07	55.46	55.85	56.23	56.62	57.01	57.39
0.2	57.78	58.16	58.54	58.93	59.31	59.69	60.07	60.45	60.83	61.21
0.3	61.58	61.96	62.33	62.71	63.08	63.45	63.82	64.19	64.56	64.93
0.4	65.29	65.66	66.02	66.38	66.74	67.10	67.46	67.81	68.17	68.52
0.5	68.87	69.22	69.57	69.92	70.27	70.61	70.95	71.29	71.63	71.97
0.6	72.30	72.64	72.97	73.30	73.63	73.96	74.28	74.60	74.92	75.24
0.7	75.56	75.88	76.19	76.50	76.81	77.12	77.42	77.72	78.02	78.32
0.8	78.62	78.91	79.21	79.50	79.79	80.07	80.36	80.64	80.92	81.19
0.9	81.47	81.74	82.01	82.28	82.55	82.81	83.07	83.33	83.59	83.84
1.0	84.10	84.35	84.59	84.84	85.08	85.32	85.56	85.80	86.03	86.26
1.1	86.49	86.72	86.94	87.16	87.38	87.60	87.82	88.03	88.24	88.45
1.2	88.65	88.86	89.06	89.26	89.45	89.65	89.84	90.03	90.21	90.40
1.3	90.58	90.76	90.94	91.12	91.29	91.46	91.63	91.80	91.96	92.12
1.4	92.28	92.44	92.60	92.75	92.90	93.05	93.20	93.34	93.48	93.62
1.5	93.76	93.90	94.03	94.17	94.30	94.42	94.55	94.67	94.80	94.92
1.6	95.03	95.15	95.26	95.38	95.49	95.60	95.70	95.81	95.91	96.01
1.7	96.11	96.21	96.30	96.40	96.49	96.58	96.67	96.75	96.84	96.92
1.8	97.01	97.09	97.17	97.24	97.32	97.39	97.46	97.54	97.61	97.67
1.9	97.74	97.81	97.87	97.93	97.99	98.05	98.11	98.17	98.22	98.28
2.0	98.33	98.38	98.43	98.48	98.53	98.58	98.62	98.67	98.71	98.75
2.1	98.80	98.84	98.88	98.91	98.95	98.99	99.02	99.06	99.09	99.12
2.2	99.15	99.19	99.22	99.24	99.27	99.30	99.33	99.35	99.38	99.40
2.3	99.42	99.45	99.47	99.49	99.51	99.53	99.55	99.57	99.59	99.60
2.4	99.62	99.64	99.65	99.67	99.68	99.70	99.71	99.72	99.74	99.75
2.5	99.76	99.77	99.78	99.79	99.80	99.81	99.82	99.83	99.84	99.85
2.6	99.86	99.86	99.87	99.88	99.88	99.89	99.90	99.90	99.91	99.91
2.7	99.92	99.92	99.93	99.93	99.93	99.94	99.94	99.95	99.95	99.95
2.8	99.96	99.96	99.96	99.96	99.97	99.97	99.97	99.97	99.97	99.98
2.9	99.98	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99
3.0	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 17 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.78	51.17	51.57	51.96	52.35	52.74	53.13	53.52
0.1	53.91	54.30	54.69	55.08	55.47	55.85	56.24	56.63	57.02	57.40
0.2	57.79	58.17	58.56	58.94	59.32	59.70	60.08	60.46	60.84	61.22
0.3	61.60	61.97	62.35	62.72	63.10	63.47	63.84	64.21	64.58	64.94
0.4	65.31	65.67	66.04	66.40	66.76	67.12	67.48	67.83	68.19	68.54
0.5	68.89	69.24	69.59	69.94	70.29	70.63	70.97	71.31	71.65	71.99
0.6	72.32	72.66	72.99	73.32	73.65	73.98	74.30	74.62	74.94	75.26
0.7	75.58	75.89	76.21	76.52	76.83	77.13	77.44	77.74	78.04	78.34
0.8	78.64	78.93	79.22	79.51	79.80	80.08	80.37	80.65	80.93	81.21
0.9	81.48	81.75	82.02	82.29	82.56	82.82	83.08	83.34	83.59	83.85
1.0	84.10	84.35	84.60	84.84	85.08	85.32	85.56	85.80	86.03	86.26
1.1	86.49	86.71	86.94	87.16	87.38	87.60	87.81	88.02	88.23	88.44
1.2	88.64	88.85	89.05	89.24	89.44	89.63	89.82	90.01	90.20	90.38
1.3	90.56	90.74	90.92	91.10	91.27	91.44	91.61	91.77	91.94	92.10
1.4	92.26	92.42	92.57	92.72	92.87	93.02	93.17	93.31	93.45	93.59
1.5	93.73	93.87	94.00	94.13	94.26	94.39	94.52	94.64	94.76	94.88
1.6	95.00	95.11	95.23	95.34	95.45	95.56	95.66	95.77	95.87	95.97
1.7	96.07	96.17	96.26	96.36	96.45	96.54	96.63	96.71	96.80	96.88
1.8	96.96	97.04	97.12	97.20	97.28	97.35	97.42	97.49	97.56	97.63
1.9	97.70	97.76	97.83	97.89	97.95	98.01	98.07	98.13	98.18	98.24
2.0	98.29	98.34	98.39	98.44	98.49	98.54	98.58	98.63	98.67	98.71
2.1	98.76	98.80	98.84	98.88	98.91	98.95	98.98	99.02	99.05	99.09
2.2	99.12	99.15	99.18	99.21	99.24	99.26	99.29	99.32	99.34	99.37
2.3	99.39	99.41	99.44	99.46	99.48	99.50	99.52	99.54	99.56	99.58
2.4	99.59	99.61	99.63	99.64	99.66	99.67	99.69	99.70	99.71	99.73
2.5	99.74	99.75	99.76	99.77	99.78	99.79	99.80	99.81	99.82	99.83
2.6	99.84	99.85	99.85	99.86	99.87	99.87	99.88	99.89	99.89	99.90
2.7	99.90	99.91	99.91	99.92	99.92	99.93	99.93	99.94	99.94	99.94
2.8	99.95	99.95	99.95	99.96	99.96	99.96	99.96	99.97	99.97	99.97
2.9	99.97	99.97	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.99
3.0	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.1	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 18 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.78	51.18	51.57	51.96	52.35	52.74	53.13	53.52
0.1	53.92	54.31	54.70	55.08	55.47	55.86	56.25	56.64	57.02	57.41
0.2	57.80	58.18	58.57	58.95	59.33	59.71	60.09	60.47	60.85	61.23
0.3	61.61	61.99	62.36	62.74	63.11	63.48	63.85	64.22	64.59	64.96
0.4	65.33	65.69	66.05	66.42	66.78	67.14	67.49	67.85	68.21	68.56
0.5	68.91	69.26	69.61	69.96	70.30	70.65	70.99	71.33	71.67	72.01
0.6	72.34	72.68	73.01	73.34	73.67	73.99	74.32	74.64	74.96	75.28
0.7	75.59	75.91	76.22	76.53	76.84	77.15	77.45	77.75	78.05	78.35
0.8	78.65	78.94	79.23	79.52	79.81	80.10	80.38	80.66	80.94	81.21
0.9	81.49	81.76	82.03	82.30	82.56	82.82	83.09	83.34	83.60	83.85
1.0	84.10	84.35	84.60	84.84	85.08	85.32	85.56	85.80	86.03	86.26
1.1	86.49	86.71	86.93	87.16	87.37	87.59	87.80	88.01	88.22	88.43
1.2	88.63	88.84	89.04	89.23	89.43	89.62	89.81	90.00	90.19	90.37
1.3	90.55	90.73	90.91	91.08	91.25	91.42	91.59	91.75	91.92	92.08
1.4	92.24	92.39	92.55	92.70	92.85	93.00	93.14	93.29	93.43	93.57
1.5	93.71	93.84	93.97	94.10	94.23	94.36	94.49	94.61	94.73	94.85
1.6	94.97	95.08	95.20	95.31	95.42	95.52	95.63	95.73	95.84	95.94
1.7	96.04	96.13	96.23	96.32	96.41	96.50	96.59	96.68	96.76	96.85
1.8	96.93	97.01	97.09	97.16	97.24	97.31	97.38	97.46	97.53	97.59
1.9	97.66	97.73	97.79	97.85	97.91	97.97	98.03	98.09	98.14	98.20
2.0	98.25	98.30	98.35	98.40	98.45	98.50	98.55	98.59	98.64	98.68
2.1	98.72	98.76	98.80	98.84	98.88	98.92	98.95	98.99	99.02	99.05
2.2	99.09	99.12	99.15	99.18	99.21	99.23	99.26	99.29	99.31	99.34
2.3	99.36	99.39	99.41	99.43	99.45	99.47	99.49	99.51	99.53	99.55
2.4	99.57	99.59	99.60	99.62	99.63	99.65	99.66	99.68	99.69	99.70
2.5	99.72	99.73	99.74	99.75	99.76	99.77	99.78	99.79	99.80	99.81
2.6	99.82	99.83	99.84	99.85	99.85	99.86	99.87	99.87	99.88	99.89
2.7	99.89	99.90	99.90	99.91	99.91	99.92	99.92	99.93	99.93	99.93
2.8	99.94	99.94	99.94	99.95	99.95	99.95	99.96	99.96	99.96	99.96
2.9	99.97	99.97	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98
3.0	99.98	99.98	99.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.1	99.99	99.99	99.99	99.99	99.99	99.99	99.99	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 19 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.78	51.18	51.57	51.96	52.35	52.75	53.14	53.53
0.1	53.92	54.31	54.70	55.09	55.48	55.87	56.26	56.64	57.03	57.42
0.2	57.80	58.19	58.57	58.96	59.34	59.72	60.10	60.49	60.87	61.24
0.3	61.62	62.00	62.37	62.75	63.12	63.49	63.87	64.24	64.60	64.97
0.4	65.34	65.70	66.07	66.43	66.79	67.15	67.51	67.87	68.22	68.57
0.5	68.93	69.28	69.63	69.97	70.32	70.66	71.01	71.35	71.69	72.02
0.6	72.36	72.69	73.02	73.35	73.68	74.01	74.33	74.65	74.97	75.29
0.7	75.61	75.92	76.24	76.55	76.85	77.16	77.46	77.77	78.07	78.36
0.8	78.66	78.95	79.25	79.53	79.82	80.11	80.39	80.67	80.95	81.22
0.9	81.50	81.77	82.04	82.30	82.57	82.83	83.09	83.35	83.60	83.86
1.0	84.11	84.36	84.60	84.84	85.09	85.33	85.56	85.80	86.03	86.26
1.1	86.48	86.71	86.93	87.15	87.37	87.59	87.80	88.01	88.22	88.42
1.2	88.63	88.83	89.03	89.22	89.42	89.61	89.80	89.99	90.17	90.36
1.3	90.54	90.71	90.89	91.06	91.24	91.41	91.57	91.74	91.90	92.06
1.4	92.22	92.37	92.53	92.68	92.83	92.98	93.12	93.27	93.41	93.55
1.5	93.68	93.82	93.95	94.08	94.21	94.34	94.46	94.58	94.70	94.82
1.6	94.94	95.05	95.17	95.28	95.39	95.49	95.60	95.70	95.81	95.91
1.7	96.00	96.10	96.20	96.29	96.38	96.47	96.56	96.65	96.73	96.81
1.8	96.89	96.97	97.05	97.13	97.21	97.28	97.35	97.42	97.49	97.56
1.9	97.63	97.69	97.76	97.82	97.88	97.94	98.00	98.06	98.11	98.17
2.0	98.22	98.27	98.32	98.37	98.42	98.47	98.52	98.56	98.61	98.65
2.1	98.69	98.73	98.77	98.81	98.85	98.89	98.92	98.96	98.99	99.02
2.2	99.06	99.09	99.12	99.15	99.18	99.21	99.24	99.26	99.29	99.31
2.3	99.34	99.36	99.38	99.41	99.43	99.45	99.47	99.49	99.51	99.53
2.4	99.55	99.56	99.58	99.60	99.61	99.63	99.64	99.66	99.67	99.69
2.5	99.70	99.71	99.72	99.74	99.75	99.76	99.77	99.78	99.79	99.80
2.6	99.81	99.82	99.82	99.83	99.84	99.85	99.85	99.86	99.87	99.87
2.7	99.88	99.89	99.89	99.90	99.90	99.91	99.91	99.92	99.92	99.93
2.8	99.93	99.93	99.94	99.94	99.94	99.95	99.95	99.95	99.95	99.96
2.9	99.96	99.96	99.96	99.97	99.97	99.97	99.97	99.97	99.98	99.98
3.0	99.98	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99
3.1	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.2	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 20 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.57	51.96	52.36	52.75	53.14	53.53
0.1	53.92	54.31	54.70	55.09	55.48	55.87	56.26	56.65	57.04	57.43
0.2	57.81	58.20	58.58	58.97	59.35	59.73	60.11	60.49	60.87	61.25
0.3	61.63	62.01	62.38	62.76	63.13	63.51	63.88	64.25	64.62	64.98
0.4	65.35	65.72	66.08	66.44	66.80	67.16	67.52	67.88	68.23	68.59
0.5	68.94	69.29	69.64	69.99	70.33	70.68	71.02	71.36	71.70	72.04
0.6	72.37	72.70	73.04	73.37	73.69	74.02	74.34	74.67	74.99	75.30
0.7	75.62	75.94	76.25	76.56	76.87	77.17	77.48	77.78	78.08	78.37
0.8	78.67	78.96	79.25	79.54	79.83	80.11	80.40	80.68	80.95	81.23
0.9	81.50	81.77	82.04	82.31	82.57	82.84	83.10	83.35	83.61	83.86
1.0	84.11	84.36	84.60	84.85	85.09	85.33	85.56	85.80	86.03	86.26
1.1	86.48	86.71	86.93	87.15	87.37	87.58	87.79	88.00	88.21	88.42
1.2	88.62	88.82	89.02	89.22	89.41	89.60	89.79	89.98	90.16	90.34
1.3	90.52	90.70	90.88	91.05	91.22	91.39	91.56	91.72	91.88	92.04
1.4	92.20	92.36	92.51	92.66	92.81	92.96	93.10	93.25	93.39	93.52
1.5	93.66	93.80	93.93	94.06	94.19	94.31	94.44	94.56	94.68	94.80
1.6	94.92	95.03	95.14	95.25	95.36	95.47	95.57	95.68	95.78	95.88
1.7	95.98	96.07	96.17	96.26	96.35	96.44	96.53	96.62	96.70	96.79
1.8	96.87	96.95	97.02	97.10	97.18	97.25	97.32	97.39	97.46	97.53
1.9	97.60	97.66	97.73	97.79	97.85	97.91	97.97	98.03	98.08	98.14
2.0	98.19	98.24	98.29	98.34	98.39	98.44	98.49	98.53	98.58	98.62
2.1	98.66	98.70	98.74	98.78	98.82	98.86	98.90	98.93	98.97	99.00
2.2	99.03	99.06	99.10	99.13	99.15	99.18	99.21	99.24	99.26	99.29
2.3	99.32	99.34	99.36	99.39	99.41	99.43	99.45	99.47	99.49	99.51
2.4	99.53	99.55	99.56	99.58	99.60	99.61	99.63	99.64	99.66	99.67
2.5	99.68	99.70	99.71	99.72	99.73	99.74	99.75	99.76	99.77	99.78
2.6	99.79	99.80	99.81	99.82	99.83	99.84	99.84	99.85	99.86	99.86
2.7	99.87	99.88	99.88	99.89	99.89	99.90	99.90	99.91	99.91	99.92
2.8	99.92	99.93	99.93	99.93	99.94	99.94	99.94	99.95	99.95	99.95
2.9	99.95	99.96	99.96	99.96	99.96	99.97	99.97	99.97	99.97	99.97
3.0	99.97	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.99	99.99
3.1	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.2	99.99	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 21 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.57	51.97	52.36	52.75	53.14	53.53
0.1	53.93	54.32	54.71	55.10	55.49	55.88	56.27	56.66	57.04	57.43
0.2	57.82	58.20	58.59	58.97	59.36	59.74	60.12	60.50	60.88	61.26
0.3	61.64	62.02	62.39	62.77	63.14	63.52	63.89	64.26	64.63	65.00
0.4	65.36	65.73	66.09	66.45	66.82	67.18	67.53	67.89	68.25	68.60
0.5	68.95	69.30	69.65	70.00	70.34	70.69	71.03	71.37	71.71	72.05
0.6	72.38	72.72	73.05	73.38	73.71	74.03	74.36	74.68	75.00	75.32
0.7	75.63	75.95	76.26	76.57	76.88	77.18	77.49	77.79	78.09	78.38
0.8	78.68	78.97	79.26	79.55	79.84	80.12	80.40	80.68	80.96	81.24
0.9	81.51	81.78	82.05	82.31	82.58	82.84	83.10	83.36	83.61	83.86
1.0	84.11	84.36	84.60	84.85	85.09	85.33	85.56	85.80	86.03	86.25
1.1	86.48	86.70	86.93	87.15	87.36	87.58	87.79	88.00	88.21	88.41
1.2	88.61	88.81	89.01	89.21	89.40	89.59	89.78	89.97	90.15	90.33
1.3	90.51	90.69	90.87	91.04	91.21	91.38	91.54	91.71	91.87	92.03
1.4	92.19	92.34	92.50	92.65	92.79	92.94	93.09	93.23	93.37	93.51
1.5	93.64	93.78	93.91	94.04	94.17	94.29	94.42	94.54	94.66	94.78
1.6	94.89	95.01	95.12	95.23	95.34	95.45	95.55	95.66	95.76	95.86
1.7	95.95	96.05	96.14	96.24	96.33	96.42	96.51	96.59	96.68	96.76
1.8	96.84	96.92	97.00	97.08	97.15	97.23	97.30	97.37	97.44	97.51
1.9	97.57	97.64	97.70	97.76	97.83	97.89	97.94	98.00	98.06	98.11
2.0	98.17	98.22	98.27	98.32	98.37	98.42	98.46	98.51	98.55	98.60
2.1	98.64	98.68	98.72	98.76	98.80	98.84	98.87	98.91	98.94	98.98
2.2	99.01	99.04	99.07	99.10	99.13	99.16	99.19	99.22	99.24	99.27
2.3	99.29	99.32	99.34	99.37	99.39	99.41	99.43	99.45	99.47	99.49
2.4	99.51	99.53	99.55	99.56	99.58	99.60	99.61	99.63	99.64	99.65
2.5	99.67	99.68	99.69	99.71	99.72	99.73	99.74	99.75	99.76	99.77
2.6	99.78	99.79	99.80	99.81	99.82	99.82	99.83	99.84	99.85	99.85
2.7	99.86	99.87	99.87	99.88	99.88	99.89	99.90	99.90	99.90	99.91
2.8	99.91	99.92	99.92	99.93	99.93	99.93	99.94	99.94	99.94	99.95
2.9	99.95	99.95	99.95	99.96	99.96	99.96	99.96	99.97	99.97	99.97
3.0	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98	99.98	99.98
3.1	99.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.2	99.99	99.99	99.99	99.99	99.99	99.99	99.99	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE				SAMPLE SIZE 22		STANDARD DEVIATION METHOD			

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.57	51.97	52.36	52.75	53.15	53.54
0.1	53.93	54.32	54.71	55.10	55.49	55.88	56.27	56.66	57.05	57.44
0.2	57.82	58.21	58.60	58.98	59.36	59.75	60.13	60.51	60.89	61.27
0.3	61.65	62.03	62.40	62.78	63.15	63.53	63.90	64.27	64.64	65.01
0.4	65.37	65.74	66.10	66.46	66.83	67.19	67.54	67.90	68.26	68.61
0.5	68.96	69.31	69.66	70.01	70.36	70.70	71.04	71.38	71.72	72.06
0.6	72.39	72.73	73.06	73.39	73.72	74.04	74.37	74.69	75.01	75.33
0.7	75.64	75.96	76.27	76.58	76.88	77.19	77.49	77.80	78.09	78.39
0.8	78.69	78.98	79.27	79.56	79.84	80.13	80.41	80.69	80.97	81.24
0.9	81.51	81.79	82.05	82.32	82.58	82.84	83.10	83.36	83.61	83.86
1.0	84.11	84.36	84.61	84.85	85.09	85.33	85.56	85.79	86.03	86.25
1.1	86.48	86.70	86.92	87.14	87.36	87.57	87.79	87.99	88.20	88.41
1.2	88.61	88.81	89.01	89.20	89.39	89.59	89.77	89.96	90.14	90.33
1.3	90.50	90.68	90.86	91.03	91.20	91.37	91.53	91.70	91.86	92.02
1.4	92.17	92.33	92.48	92.63	92.78	92.93	93.07	93.21	93.35	93.49
1.5	93.63	93.76	93.89	94.02	94.15	94.27	94.40	94.52	94.64	94.76
1.6	94.87	94.99	95.10	95.21	95.32	95.43	95.53	95.63	95.74	95.84
1.7	95.93	96.03	96.12	96.22	96.31	96.40	96.48	96.57	96.65	96.74
1.8	96.82	96.90	96.98	97.05	97.13	97.20	97.27	97.35	97.41	97.48
1.9	97.55	97.61	97.68	97.74	97.80	97.86	97.92	97.98	98.03	98.09
2.0	98.14	98.20	98.25	98.30	98.35	98.39	98.44	98.49	98.53	98.57
2.1	98.62	98.66	98.70	98.74	98.78	98.81	98.85	98.89	98.92	98.96
2.2	98.99	99.02	99.05	99.08	99.11	99.14	99.17	99.20	99.23	99.25
2.3	99.28	99.30	99.33	99.35	99.37	99.39	99.41	99.44	99.46	99.47
2.4	99.49	99.51	99.53	99.55	99.56	99.58	99.60	99.61	99.63	99.64
2.5	99.65	99.67	99.68	99.69	99.71	99.72	99.73	99.74	99.75	99.76
2.6	99.77	99.78	99.79	99.80	99.81	99.81	99.82	99.83	99.84	99.84
2.7	99.85	99.86	99.86	99.87	99.88	99.88	99.89	99.89	99.90	99.90
2.8	99.91	99.91	99.92	99.92	99.92	99.93	99.93	99.93	99.94	99.94
2.9	99.94	99.95	99.95	99.95	99.95	99.96	99.96	99.96	99.96	99.97
3.0	99.97	99.97	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98
3.1	99.98	99.98	99.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.2	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 23 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.57	51.97	52.36	52.75	53.15	53.54
0.1	53.93	54.32	54.72	55.11	55.50	55.89	56.28	56.67	57.05	57.44
0.2	57.83	58.22	58.60	58.99	59.37	59.75	60.14	60.52	60.90	61.28
0.3	61.66	62.03	62.41	62.79	63.16	63.53	63.91	64.28	64.65	65.01
0.4	65.38	65.75	66.11	66.47	66.83	67.19	67.55	67.91	68.27	68.62
0.5	68.97	69.32	69.67	70.02	70.36	70.71	71.05	71.39	71.73	72.07
0.6	72.40	72.74	73.07	73.40	73.73	74.05	74.37	74.70	75.02	75.33
0.7	75.65	75.96	76.28	76.59	76.89	77.20	77.50	77.80	78.10	78.40
0.8	78.69	78.99	79.28	79.57	79.85	80.13	80.42	80.70	80.97	81.25
0.9	81.52	81.79	82.06	82.32	82.59	82.85	83.11	83.36	83.62	83.87
1.0	84.12	84.36	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.48	86.70	86.92	87.14	87.36	87.57	87.78	87.99	88.20	88.40
1.2	88.60	88.80	89.00	89.20	89.39	89.58	89.77	89.95	90.14	90.32
1.3	90.50	90.67	90.85	91.02	91.19	91.36	91.52	91.69	91.85	92.01
1.4	92.16	92.32	92.47	92.62	92.77	92.91	93.06	93.20	93.34	93.48
1.5	93.61	93.74	93.88	94.01	94.13	94.26	94.38	94.50	94.62	94.74
1.6	94.86	94.97	95.08	95.19	95.30	95.41	95.51	95.62	95.72	95.82
1.7	95.91	96.01	96.10	96.20	96.29	96.38	96.46	96.55	96.63	96.72
1.8	96.80	96.88	96.96	97.03	97.11	97.18	97.25	97.32	97.39	97.46
1.9	97.53	97.59	97.66	97.72	97.78	97.84	97.90	97.96	98.01	98.07
2.0	98.12	98.17	98.23	98.28	98.33	98.37	98.42	98.47	98.51	98.55
2.1	98.60	98.64	98.68	98.72	98.76	98.80	98.83	98.87	98.90	98.94
2.2	98.97	99.00	99.04	99.07	99.10	99.13	99.15	99.18	99.21	99.23
2.3	99.26	99.29	99.31	99.33	99.36	99.38	99.40	99.42	99.44	99.46
2.4	99.48	99.50	99.52	99.53	99.55	99.57	99.58	99.60	99.61	99.63
2.5	99.64	99.66	99.67	99.68	99.69	99.71	99.72	99.73	99.74	99.75
2.6	99.76	99.77	99.78	99.79	99.80	99.81	99.81	99.82	99.83	99.84
2.7	99.84	99.85	99.86	99.86	99.87	99.87	99.88	99.89	99.89	99.90
2.8	99.90	99.91	99.91	99.91	99.92	99.92	99.93	99.93	99.93	99.94
2.9	99.94	99.94	99.95	99.95	99.95	99.95	99.96	99.96	99.96	99.96
3.0	99.96	99.97	99.97	99.97	99.97	99.97	99.97	99.98	99.98	99.98
3.1	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99	99.99
3.2	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.3	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE

SAMPLE SIZE 24

STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.58	51.97	52.36	52.76	53.15	53.54
0.1	53.93	54.33	54.72	55.11	55.50	55.89	56.28	56.67	57.06	57.45
0.2	57.83	58.22	58.61	58.99	59.38	59.76	60.14	60.52	60.90	61.28
0.3	61.66	62.04	62.42	62.79	63.17	63.54	63.91	64.28	64.65	65.02
0.4	65.39	65.75	66.12	66.48	66.84	67.20	67.56	67.92	68.27	68.63
0.5	68.98	69.33	69.68	70.03	70.37	70.72	71.06	71.40	71.74	72.08
0.6	72.41	72.74	73.08	73.41	73.73	74.06	74.38	74.70	75.02	75.34
0.7	75.66	75.97	76.28	76.59	76.90	77.21	77.51	77.81	78.11	78.41
0.8	78.70	78.99	79.28	79.57	79.86	80.14	80.42	80.70	80.98	81.25
0.9	81.52	81.79	82.06	82.33	82.59	82.85	83.11	83.36	83.62	83.87
1.0	84.12	84.36	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.48	86.70	86.92	87.14	87.35	87.57	87.78	87.99	88.19	88.40
1.2	88.60	88.80	89.00	89.19	89.38	89.57	89.76	89.95	90.13	90.31
1.3	90.49	90.66	90.84	91.01	91.18	91.35	91.51	91.68	91.84	91.99
1.4	92.15	92.31	92.46	92.61	92.76	92.90	93.04	93.19	93.33	93.46
1.5	93.60	93.73	93.86	93.99	94.12	94.24	94.37	94.49	94.61	94.73
1.6	94.84	94.95	95.07	95.18	95.28	95.39	95.50	95.60	95.70	95.80
1.7	95.90	95.99	96.09	96.18	96.27	96.36	96.45	96.53	96.62	96.70
1.8	96.78	96.86	96.94	97.01	97.09	97.16	97.24	97.31	97.38	97.44
1.9	97.51	97.57	97.64	97.70	97.76	97.82	97.88	97.94	97.99	98.05
2.0	98.10	98.16	98.21	98.26	98.31	98.36	98.40	98.45	98.49	98.54
2.1	98.58	98.62	98.66	98.70	98.74	98.78	98.82	98.85	98.89	98.92
2.2	98.95	98.99	99.02	99.05	99.08	99.11	99.14	99.17	99.19	99.22
2.3	99.25	99.27	99.29	99.32	99.34	99.36	99.39	99.41	99.43	99.45
2.4	99.47	99.48	99.50	99.52	99.54	99.55	99.57	99.59	99.60	99.62
2.5	99.63	99.64	99.66	99.67	99.68	99.70	99.71	99.72	99.73	99.74
2.6	99.75	99.76	99.77	99.78	99.79	99.80	99.81	99.81	99.82	99.83
2.7	99.84	99.84	99.85	99.86	99.86	99.87	99.87	99.88	99.88	99.89
2.8	99.90	99.90	99.90	99.91	99.91	99.92	99.92	99.92	99.93	99.93
2.9	99.94	99.94	99.94	99.94	99.95	99.95	99.95	99.95	99.96	99.96
3.0	99.96	99.96	99.97	99.97	99.97	99.97	99.97	99.97	99.98	99.98
3.1	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99
3.2	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.3	99.99	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 25 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.58	51.97	52.36	52.76	53.15	53.54
0.1	53.94	54.33	54.72	55.11	55.50	55.89	56.28	56.67	57.06	57.45
0.2	57.84	58.22	58.61	59.00	59.38	59.76	60.15	60.53	60.91	61.29
0.3	61.67	62.05	62.42	62.80	63.17	63.55	63.92	64.29	64.66	65.03
0.4	65.40	65.76	66.13	66.49	66.85	67.21	67.57	67.93	68.28	68.64
0.5	68.99	69.34	69.69	70.04	70.38	70.73	71.07	71.41	71.75	72.08
0.6	72.42	72.75	73.08	73.41	73.74	74.07	74.39	74.71	75.03	75.35
0.7	75.67	75.98	76.29	76.60	76.91	77.21	77.52	77.82	78.11	78.41
0.8	78.71	79.00	79.29	79.58	79.86	80.14	80.43	80.70	80.98	81.26
0.9	81.53	81.80	82.06	82.33	82.59	82.85	83.11	83.37	83.62	83.87
1.0	84.12	84.37	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.48	86.70	86.92	87.14	87.35	87.56	87.78	87.98	88.19	88.39
1.2	88.59	88.79	88.99	89.18	89.38	89.57	89.75	89.94	90.12	90.30
1.3	90.48	90.66	90.83	91.00	91.17	91.34	91.50	91.67	91.83	91.99
1.4	92.14	92.30	92.45	92.60	92.74	92.89	93.03	93.17	93.31	93.45
1.5	93.59	93.72	93.85	93.98	94.11	94.23	94.35	94.47	94.59	94.71
1.6	94.83	94.94	95.05	95.16	95.27	95.38	95.48	95.58	95.68	95.78
1.7	95.88	95.98	96.07	96.16	96.25	96.34	96.43	96.52	96.60	96.68
1.8	96.76	96.84	96.92	97.00	97.07	97.15	97.22	97.29	97.36	97.43
1.9	97.49	97.56	97.62	97.68	97.75	97.81	97.86	97.92	97.98	98.03
2.0	98.09	98.14	98.19	98.24	98.29	98.34	98.39	98.43	98.48	98.52
2.1	98.56	98.61	98.65	98.69	98.72	98.76	98.80	98.84	98.87	98.91
2.2	98.94	98.97	99.00	99.04	99.07	99.09	99.12	99.15	99.18	99.21
2.3	99.23	99.26	99.28	99.30	99.33	99.35	99.37	99.39	99.41	99.43
2.4	99.45	99.47	99.49	99.51	99.53	99.54	99.56	99.58	99.59	99.61
2.5	99.62	99.63	99.65	99.66	99.67	99.69	99.70	99.71	99.72	99.73
2.6	99.74	99.75	99.76	99.77	99.78	99.79	99.80	99.81	99.81	99.82
2.7	99.83	99.84	99.84	99.85	99.86	99.86	99.87	99.87	99.88	99.88
2.8	99.89	99.89	99.90	99.90	99.91	99.91	99.92	99.92	99.92	99.93
2.9	99.93	99.93	99.94	99.94	99.94	99.95	99.95	99.95	99.95	99.96
3.0	99.96	99.96	99.96	99.96	99.97	99.97	99.97	99.97	99.97	99.97
3.1	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.99
3.2	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.3	99.99	99.99	99.99	99.99	99.99	99.99	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 26 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.58	51.97	52.37	52.76	53.15	53.55
0.1	53.94	54.33	54.72	55.12	55.51	55.90	56.29	56.68	57.07	57.45
0.2	57.84	58.23	58.62	59.00	59.39	59.77	60.15	60.53	60.92	61.30
0.3	61.67	62.05	62.43	62.80	63.18	63.55	63.93	64.30	64.67	65.03
0.4	65.40	65.77	66.13	66.50	66.86	67.22	67.58	67.93	68.29	68.64
0.5	69.00	69.35	69.70	70.04	70.39	70.73	71.08	71.42	71.75	72.09
0.6	72.43	72.76	73.09	73.42	73.75	74.07	74.40	74.72	75.04	75.36
0.7	75.67	75.98	76.30	76.61	76.91	77.22	77.52	77.82	78.12	78.42
0.8	78.71	79.00	79.29	79.58	79.87	80.15	80.43	80.71	80.99	81.26
0.9	81.53	81.80	82.07	82.33	82.59	82.85	83.11	83.37	83.62	83.87
1.0	84.12	84.37	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.47	86.70	86.92	87.13	87.35	87.56	87.77	87.98	88.19	88.39
1.2	88.59	88.79	88.99	89.18	89.37	89.56	89.75	89.93	90.12	90.30
1.3	90.47	90.65	90.82	91.00	91.16	91.33	91.50	91.66	91.82	91.98
1.4	92.13	92.29	92.44	92.59	92.73	92.88	93.02	93.16	93.30	93.44
1.5	93.57	93.71	93.84	93.97	94.09	94.22	94.34	94.46	94.58	94.70
1.6	94.81	94.93	95.04	95.15	95.26	95.36	95.47	95.57	95.67	95.77
1.7	95.87	95.96	96.06	96.15	96.24	96.33	96.41	96.50	96.58	96.67
1.8	96.75	96.83	96.91	96.98	97.06	97.13	97.20	97.27	97.34	97.41
1.9	97.48	97.54	97.61	97.67	97.73	97.79	97.85	97.91	97.96	98.02
2.0	98.07	98.12	98.18	98.23	98.28	98.32	98.37	98.42	98.46	98.51
2.1	98.55	98.59	98.63	98.67	98.71	98.75	98.79	98.82	98.86	98.89
2.2	98.93	98.96	98.99	99.02	99.05	99.08	99.11	99.14	99.17	99.19
2.3	99.22	99.24	99.27	99.29	99.32	99.34	99.36	99.38	99.40	99.42
2.4	99.44	99.46	99.48	99.50	99.52	99.53	99.55	99.57	99.58	99.60
2.5	99.61	99.62	99.64	99.65	99.66	99.68	99.69	99.70	99.71	99.72
2.6	99.73	99.74	99.75	99.76	99.77	99.78	99.79	99.80	99.81	99.81
2.7	99.82	99.83	99.84	99.84	99.85	99.86	99.86	99.87	99.87	99.88
2.8	99.88	99.89	99.89	99.90	99.90	99.91	99.91	99.92	99.92	99.92
2.9	99.93	99.93	99.93	99.94	99.94	99.94	99.95	99.95	99.95	99.95
3.0	99.96	99.96	99.96	99.96	99.96	99.97	99.97	99.97	99.97	99.97
3.1	99.97	99.97	99.98	99.98	99.98	99.98	99.98	99.98	99.98	99.98
3.2	99.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.3	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 27 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.58	51.97	52.37	52.76	53.15	53.55
0.1	53.94	54.33	54.73	55.12	55.51	55.90	56.29	56.68	57.07	57.46
0.2	57.85	58.23	58.62	59.00	59.39	59.77	60.16	60.54	60.92	61.30
0.3	61.68	62.06	62.43	62.81	63.18	63.56	63.93	64.30	64.67	65.04
0.4	65.41	65.77	66.14	66.50	66.86	67.22	67.58	67.94	68.30	68.65
0.5	69.00	69.35	69.70	70.05	70.40	70.74	71.08	71.42	71.76	72.10
0.6	72.43	72.77	73.10	73.43	73.75	74.08	74.40	74.72	75.04	75.36
0.7	75.68	75.99	76.30	76.61	76.92	77.22	77.53	77.83	78.13	78.42
0.8	78.72	79.01	79.30	79.58	79.87	80.15	80.43	80.71	80.99	81.26
0.9	81.53	81.80	82.07	82.33	82.60	82.86	83.11	83.37	83.62	83.87
1.0	84.12	84.37	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.47	86.69	86.91	87.13	87.35	87.56	87.77	87.98	88.18	88.39
1.2	88.59	88.79	88.98	89.18	89.37	89.56	89.74	89.93	90.11	90.29
1.3	90.47	90.64	90.82	90.99	91.16	91.32	91.49	91.65	91.81	91.97
1.4	92.12	92.28	92.43	92.58	92.73	92.87	93.01	93.15	93.29	93.43
1.5	93.56	93.70	93.83	93.96	94.08	94.21	94.33	94.45	94.57	94.69
1.6	94.80	94.92	95.03	95.14	95.24	95.35	95.45	95.56	95.66	95.76
1.7	95.85	95.95	96.04	96.13	96.22	96.31	96.40	96.49	96.57	96.65
1.8	96.73	96.81	96.89	96.97	97.04	97.12	97.19	97.26	97.33	97.40
1.9	97.46	97.53	97.59	97.65	97.72	97.78	97.83	97.89	97.95	98.00
2.0	98.06	98.11	98.16	98.21	98.26	98.31	98.36	98.40	98.45	98.49
2.1	98.53	98.58	98.62	98.66	98.70	98.74	98.77	98.81	98.84	98.88
2.2	98.91	98.95	98.98	99.01	99.04	99.07	99.10	99.13	99.15	99.18
2.3	99.21	99.23	99.26	99.28	99.30	99.33	99.35	99.37	99.39	99.41
2.4	99.43	99.45	99.47	99.49	99.51	99.52	99.54	99.56	99.57	99.59
2.5	99.60	99.62	99.63	99.64	99.66	99.67	99.68	99.69	99.70	99.72
2.6	99.73	99.74	99.75	99.76	99.77	99.78	99.78	99.79	99.80	99.81
2.7	99.82	99.82	99.83	99.84	99.84	99.85	99.86	99.86	99.87	99.87
2.8	99.88	99.88	99.89	99.89	99.90	99.90	99.91	99.91	99.92	99.92
2.9	99.92	99.93	99.93	99.93	99.94	99.94	99.94	99.95	99.95	99.95
3.0	99.95	99.95	99.96	99.96	99.96	99.96	99.96	99.97	99.97	99.97
3.1	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98	99.98	99.98
3.2	99.98	99.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.3	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 28 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.58	51.97	52.37	52.76	53.16	53.55
0.1	53.94	54.34	54.73	55.12	55.51	55.90	56.29	56.68	57.07	57.46
0.2	57.85	58.24	58.62	59.01	59.39	59.78	60.16	60.54	60.92	61.30
0.3	61.68	62.06	62.44	62.82	63.19	63.56	63.94	64.31	64.68	65.05
0.4	65.41	65.78	66.14	66.51	66.87	67.23	67.59	67.95	68.30	68.66
0.5	69.01	69.36	69.71	70.06	70.40	70.75	71.09	71.43	71.77	72.10
0.6	72.44	72.77	73.10	73.43	73.76	74.09	74.41	74.73	75.05	75.37
0.7	75.68	76.00	76.31	76.62	76.92	77.23	77.53	77.83	78.13	78.43
0.8	78.72	79.01	79.30	79.59	79.87	80.16	80.44	80.72	80.99	81.27
0.9	81.54	81.81	82.07	82.34	82.60	82.86	83.12	83.37	83.62	83.87
1.0	84.12	84.37	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.47	86.69	86.91	87.13	87.34	87.56	87.77	87.97	88.18	88.38
1.2	88.58	88.78	88.98	89.17	89.36	89.55	89.74	89.92	90.11	90.29
1.3	90.46	90.64	90.81	90.98	91.15	91.32	91.48	91.64	91.80	91.96
1.4	92.12	92.27	92.42	92.57	92.72	92.86	93.00	93.14	93.28	93.42
1.5	93.55	93.69	93.82	93.95	94.07	94.20	94.32	94.44	94.56	94.68
1.6	94.79	94.90	95.02	95.12	95.23	95.34	95.44	95.54	95.64	95.74
1.7	95.84	95.94	96.03	96.12	96.21	96.30	96.39	96.47	96.56	96.64
1.8	96.72	96.80	96.88	96.95	97.03	97.10	97.17	97.25	97.31	97.38
1.9	97.45	97.51	97.58	97.64	97.70	97.76	97.82	97.88	97.93	97.99
2.0	98.04	98.10	98.15	98.20	98.25	98.30	98.34	98.39	98.43	98.48
2.1	98.52	98.56	98.61	98.65	98.68	98.72	98.76	98.80	98.83	98.87
2.2	98.90	98.93	98.97	99.00	99.03	99.06	99.09	99.12	99.14	99.17
2.3	99.20	99.22	99.25	99.27	99.29	99.32	99.34	99.36	99.38	99.40
2.4	99.42	99.44	99.46	99.48	99.50	99.51	99.53	99.55	99.56	99.58
2.5	99.59	99.61	99.62	99.64	99.65	99.66	99.67	99.69	99.70	99.71
2.6	99.72	99.73	99.74	99.75	99.76	99.77	99.78	99.79	99.79	99.80
2.7	99.81	99.82	99.83	99.83	99.84	99.85	99.85	99.86	99.86	99.87
2.8	99.88	99.88	99.89	99.89	99.90	99.90	99.90	99.91	99.91	99.92
2.9	99.92	99.92	99.93	99.93	99.93	99.94	99.94	99.94	99.94	99.95
3.0	99.95	99.95	99.95	99.96	99.96	99.96	99.96	99.96	99.97	99.97
3.1	99.97	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98	99.98
3.2	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99	99.99	99.99
3.3	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.4	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 29 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.39	50.79	51.18	51.58	51.97	52.37	52.76	53.16	53.55
0.1	53.94	54.34	54.73	55.12	55.51	55.90	56.30	56.69	57.07	57.46
0.2	57.85	58.24	58.63	59.01	59.40	59.78	60.16	60.55	60.93	61.31
0.3	61.69	62.07	62.44	62.82	63.19	63.57	63.94	64.31	64.68	65.05
0.4	65.42	65.78	66.15	66.51	66.87	67.23	67.59	67.95	68.31	68.66
0.5	69.01	69.36	69.71	70.06	70.41	70.75	71.09	71.43	71.77	72.11
0.6	72.44	72.78	73.11	73.44	73.77	74.09	74.41	74.74	75.05	75.37
0.7	75.69	76.00	76.31	76.62	76.93	77.23	77.54	77.84	78.13	78.43
0.8	78.72	79.02	79.31	79.59	79.88	80.16	80.44	80.72	80.99	81.27
0.9	81.54	81.81	82.07	82.34	82.60	82.86	83.12	83.37	83.63	83.88
1.0	84.12	84.37	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.47	86.69	86.91	87.13	87.34	87.56	87.76	87.97	88.18	88.38
1.2	88.58	88.78	88.97	89.17	89.36	89.55	89.73	89.92	90.10	90.28
1.3	90.46	90.63	90.81	90.98	91.15	91.31	91.48	91.64	91.80	91.95
1.4	92.11	92.26	92.41	92.56	92.71	92.85	93.00	93.14	93.27	93.41
1.5	93.55	93.68	93.81	93.94	94.06	94.19	94.31	94.43	94.55	94.67
1.6	94.78	94.89	95.00	95.11	95.22	95.33	95.43	95.53	95.63	95.73
1.7	95.83	95.92	96.02	96.11	96.20	96.29	96.38	96.46	96.55	96.63
1.8	96.71	96.79	96.87	96.94	97.02	97.09	97.16	97.23	97.30	97.37
1.9	97.44	97.50	97.57	97.63	97.69	97.75	97.81	97.87	97.92	97.98
2.0	98.03	98.08	98.14	98.19	98.24	98.28	98.33	98.38	98.42	98.47
2.1	98.51	98.55	98.59	98.63	98.67	98.71	98.75	98.79	98.82	98.86
2.2	98.89	98.92	98.96	98.99	99.02	99.05	99.08	99.11	99.13	99.16
2.3	99.19	99.21	99.24	99.26	99.29	99.31	99.33	99.35	99.37	99.39
2.4	99.41	99.43	99.45	99.47	99.49	99.51	99.52	99.54	99.56	99.57
2.5	99.59	99.60	99.61	99.63	99.64	99.65	99.67	99.68	99.69	99.70
2.6	99.71	99.72	99.73	99.74	99.75	99.76	99.77	99.78	99.79	99.80
2.7	99.81	99.81	99.82	99.83	99.83	99.84	99.85	99.85	99.86	99.87
2.8	99.87	99.88	99.88	99.89	99.89	99.90	99.90	99.90	99.91	99.91
2.9	99.92	99.92	99.92	99.93	99.93	99.93	99.94	99.94	99.94	99.94
3.0	99.95	99.95	99.95	99.95	99.96	99.96	99.96	99.96	99.96	99.97
3.1	99.97	99.97	99.97	99.97	99.97	99.98	99.98	99.98	99.98	99.98
3.2	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99	99.99
3.3	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.4	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

PERCENT WITHIN LIMITS ESTIMATION TABLE

VARIABILITY-UNKNOWN PROCEDURE — SAMPLE SIZE 30 — STANDARD DEVIATION METHOD

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.40	50.79	51.19	51.58	51.98	52.37	52.76	53.16	53.55
0.1	53.95	54.34	54.73	55.12	55.52	55.91	56.30	56.69	57.08	57.47
0.2	57.85	58.24	58.63	59.01	59.40	59.78	60.17	60.55	60.93	61.31
0.3	61.69	62.07	62.45	62.82	63.20	63.57	63.95	64.32	64.69	65.06
0.4	65.42	65.79	66.15	66.52	66.88	67.24	67.60	67.96	68.31	68.67
0.5	69.02	69.37	69.72	70.07	70.41	70.76	71.10	71.44	71.78	72.11
0.6	72.45	72.78	73.11	73.44	73.77	74.10	74.42	74.74	75.06	75.38
0.7	75.69	76.01	76.32	76.63	76.93	77.24	77.54	77.84	78.14	78.43
0.8	78.73	79.02	79.31	79.60	79.88	80.16	80.44	80.72	81.00	81.27
0.9	81.54	81.81	82.08	82.34	82.60	82.86	83.12	83.37	83.63	83.88
1.0	84.12	84.37	84.61	84.85	85.09	85.33	85.56	85.79	86.02	86.25
1.1	86.47	86.69	86.91	87.13	87.34	87.55	87.76	87.97	88.18	88.38
1.2	88.58	88.78	88.97	89.16	89.36	89.54	89.73	89.91	90.10	90.28
1.3	90.45	90.63	90.80	90.97	91.14	91.31	91.47	91.63	91.79	91.95
1.4	92.10	92.26	92.41	92.56	92.70	92.85	92.99	93.13	93.27	93.40
1.5	93.54	93.67	93.80	93.93	94.05	94.18	94.30	94.42	94.54	94.66
1.6	94.77	94.88	94.99	95.10	95.21	95.32	95.42	95.52	95.62	95.72
1.7	95.82	95.91	96.01	96.10	96.19	96.28	96.37	96.45	96.53	96.62
1.8	96.70	96.78	96.85	96.93	97.01	97.08	97.15	97.22	97.29	97.36
1.9	97.43	97.49	97.55	97.62	97.68	97.74	97.80	97.86	97.91	97.97
2.0	98.02	98.07	98.13	98.18	98.23	98.27	98.32	98.37	98.41	98.46
2.1	98.50	98.54	98.58	98.62	98.66	98.70	98.74	98.78	98.81	98.85
2.2	98.88	98.91	98.95	98.98	99.01	99.04	99.07	99.10	99.12	99.15
2.3	99.18	99.20	99.23	99.25	99.28	99.30	99.32	99.34	99.37	99.39
2.4	99.41	99.43	99.44	99.46	99.48	99.50	99.52	99.53	99.55	99.56
2.5	99.58	99.59	99.61	99.62	99.63	99.65	99.66	99.67	99.68	99.70
2.6	99.71	99.72	99.73	99.74	99.75	99.76	99.77	99.78	99.78	99.79
2.7	99.80	99.81	99.82	99.82	99.83	99.84	99.84	99.85	99.86	99.86
2.8	99.87	99.87	99.88	99.88	99.89	99.89	99.90	99.90	99.91	99.91
2.9	99.91	99.92	99.92	99.92	99.93	99.93	99.93	99.94	99.94	99.94
3.0	99.95	99.95	99.95	99.95	99.95	99.96	99.96	99.96	99.96	99.96
3.1	99.97	99.97	99.97	99.97	99.97	99.97	99.98	99.98	99.98	99.98
3.2	99.98	99.98	99.98	99.98	99.98	99.98	99.99	99.99	99.99	99.99
3.3	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
3.4	99.99	99.99	99.99	99.99	99.99	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q = (AVERAGE - LOWER LIMIT) / (STANDARD DEVIATION) OR Q = (UPPER LIMIT - AVERAGE) / (STANDARD DEVIATION). FOR NEGATIVE Q VALUES, THE TABLE VALUES MUST BE SUBTRACTED FROM 100.

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