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Standard Practice for
Factors and Procedures for Applying the MIL-STD-105 Plans in Life and Reliability Inspection[1]

This standard is issued under the fixed designation E2555; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice presents a procedure and related tables of factors for adapting Practice E2234 (equivalent to MIL-STD-105) sampling plans to acceptance sampling inspection when the item quality of interest is life length or reliability. Factors are provided for three alternative criteria for lot evaluation: mean life, hazard rate, and reliable life. Inspection of the sample is by attributes with testing truncated at the end of some prearranged period of time. The Weibull distribution, together with the exponential distribution as a special case, is used as the underlying statistical model.

1.2 A system of units is not specified by this practice.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E456 Terminology Relating to Quality and Statistics

E2234 Practice for Sampling a Stream of Product by Attributes Indexed by AQL

2.2 *Other Documents:*

MIL-STD-105E Sampling Procedures and Tables for Inspection by Attributes[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The terminology defined in Terminology E456 applies to this practice unless modified herein.

3.1.2 *acceptance quality level (AQL), n*—quality limit that is the worst tolerable process average when a continuing series of lots is submitted for acceptance sampling. **E2234**

3.1.2.1 *Discussion—*

This term is often referred to as the "acceptance quality limit."

3.1.2.2 *Discussion—*

This definition supersedes that given in MIL-STD-105E.

3.1.2.3 *Discussion—*

[1] This practice is under the jurisdiction of ASTM Committee E11 on Quality and Statistics and is the direct responsibility of Subcommittee E11.40 on Reliability.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] MIL-STD-105E is also commonly referred to as "MIL-STD-105." It is virtually identical in content to its predecessor, MIL-STD-105D. These documents are out of print.

A sampling plan and an AQL are chosen in accordance with the risk assumed. Use of a value of AQL for a certain defect or group of defects indicates that the sampling plan will accept the great majority of the lots or batches provided the process average level of percent defective (or defects per hundred units) in these lots or batches are no greater than the designated value of AQL. Thus, the AQL is a designated value of percent defective (or defects per hundred units) for which lots will be accepted most of the time by the sampling procedure being used. The sampling plans provided herein are so arranged that the probability of acceptance at the designated AQL value depends upon the sample size, being generally higher for large samples than for small ones, for a given AQL. The AQL alone does not identify the chances of accepting or rejecting individual lots or batches but more directly relates to what might be expected from a series of lots or batches, provided the steps indicated in this refer to the operating characteristic curve of the plan to determine the relative risks.

3.1.3 *consumer's risk, n*—probability that a lot having specified rejectable quality level will be accepted under a defined sampling plan.

3.1.4 *double sampling plan, n*—a multiple sampling plan in which up to two samplings can be taken and evaluated to accept or reject a lot.

3.1.5 *limiting quality level (LQL), n*—quality level having a specified consumer's risk for a given sampling plan.

3.1.6 *lot, n*—a definite quantity of a product or material accumulated under conditions that are considered uniform for sampling purposes.

3.1.6.1 *Discussion*—

The lot for sampling may differ from a collection of units designated as a batch for other purposes, for example, production, shipment, and so forth.

3.1.7 *multiple sampling plan, n*—a sampling plan in which successive samples from a lot are drawn and after each sample is inspected a decision is made to accept the lot, reject the lot, or to take another sample, based on quality level of the combined samples.

3.1.7.1 *Discussion*—

When the quality is much less or much more than the AQL, the decision can be made on the first sample, which is smaller than that of a single sampling plan with equivalent acceptance quality level. For samples that are close to the AQL in quality, additional samples are required and the total sample size will be larger than the corresponding single sampling plan.

3.1.8 *sample, n*—group of items, observations, test results, or portions of material taken from a large collection of items, observations, test results, or quantities of material that serves to provide information that may be used as a basis for making a decision concerning the larger collection. **E2234**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceptance number, n*—the maximum number of failed items allowed in the sample for the lot to be accepted using a single or multiple sampling plan.

3.2.2 *hazard rate, n*—differential fraction of items failing at time t among those surviving up to time t, symbolized by $h(t)$.

3.2.2.1 *Discussion*—

$h(t)$ is also referred to as the instantaneous failure rate at time t. It is related to the probability density and cumulative distribution functions by $h(t) = f(t)\ /(1 - F(t))$.

3.2.3 *mean life, n*—average time that items in the lot or population are expected to operate before failure.

3.2.3.1 *Discussion*—

This metric is often referred to as mean time to failure (MTTF) or mean time before failure (MTBF).

3.2.4 *rejection number, n*—the minimum number of failed items in the sample that will cause the lot to be rejected under a given sampling plan.

3.2.5 *reliable life* (ρ_r~~) ,~~), *n*—life beyond which some specified proportion, r, of the items in the lot or population will survive.

3.2.6 *test truncation time (t), n*—amount of time sampled items are allowed to be tested.

3.2.7 *Weibull distribution, n*—probability distribution having cumulative distribution:

$$\text{function } F(t) = 1 - \exp\left(-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right), t > \gamma \text{ and probability density}$$

$$\text{function } f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \exp\left(-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right)$$

3.2.7.1 *Discussion*—

The Weibull distribution is widely used for modeling product life. It can take a wide variety of shapes and also the characteristics of other types of distributions based on the value of its parameters. γ is called the location, minimum life, or threshold parameter and defines the lower limit of the distribution (Fig. 1). η is called the scale or characteristic life parameter and is equal to the 63.2 percentile of the distribution, minus γ (Fig. 2). β is the shape parameter (Fig. 3). The exponential distribution is the special case where γ = 0 and β = l.

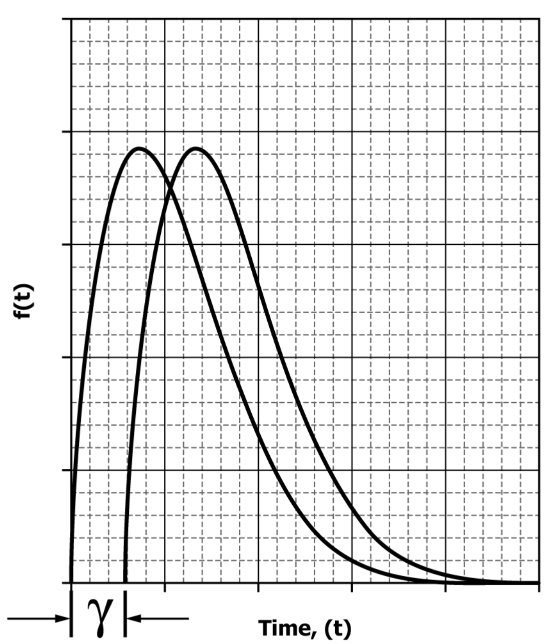

FIG. 1 Effect of the Parameter γ on the Weibull Probability Density Function, *f(t)*

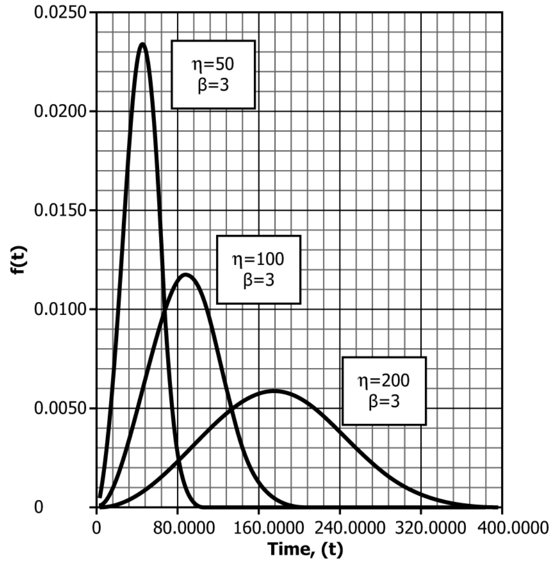

FIG. 2 Effect of the Parameter η on the Weibull Probability Density Function, *f(t)*

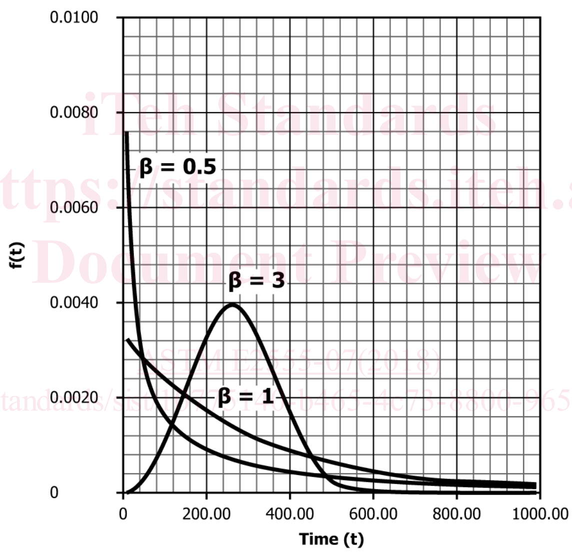

FIG. 3 Effect of the Parameter β on the Weibull Probability Density Function, *f(t)*

4. Significance and Use

4.1 The procedure and tables presented in this practice are based on the use of the Weibull distribution in acceptance sampling inspection. Details of this work, together with tables of sampling plans of other forms, have been published previously. See Refs (**1-3**).[4] Since the basic computations required have already been made, it has been quite easy to provide these new factors. No changes in method or details of application have been made over those described in the publications referenced above. For this reason, the text portion of this report has been briefly written. Readers interested in further details are referred to these previous publications. Other sources of material on the underlying theory and approach are also available (**4-7**).

4.2 The procedure to be used is essentially the same as the one normally used for attribute sampling inspection. The only difference is that sample items are tested for life or survival instead of for some other property. For single sampling, the following are the required steps:

4.2.1 Using the tables of factors provided in Annex A1, select a suitable sampling inspection plan from those tabulated in Practice E2234.

4.2.2 Draw at random a sample of items of the size specified by the selected Practice E2234 plan.

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

4.2.3 Place the sample of items on life test for the specified period of time, *t*.

4.2.4 Determine the number of sample items that failed during the test period.

4.2.5 Compare the number of items that failed with the number allowed under the selected Practice E2234 plan.

4.2.6 If the number that failed is equal to or less than the acceptable number, accept the lot; if the number failing exceeds the acceptable number, reject the lot.

4.3 Both the sample sizes and the acceptance numbers used are those specified by Practice E2234 plans. It will be assumed in the section on examples that single sampling plans will be used. However, the matching double sampling and multiple sampling plans provided in MIL-STD-105 can be used if desired. The corresponding sample sizes and acceptance and rejection numbers are used in the usual way. The specified test truncation time, *t*, must be used for all samples.

4.4 The probability of acceptance for a lot under this procedure depends only on the probability of a sample item failing before the end of the test truncation time, *t*. For this reason, the actual life at failure need not be determined; only the number of items failing is of interest. Life requirements and test time specifications need not necessarily be measured in chronological terms such as minutes or hours. For example, the life measure may be cycles of operation, revolutions, or miles of travel.

4.5 The underlying life distribution assumed in this standard is the Weibull distribution (note that the exponential distribution is a special case of the Weibull). The Weibull model has three parameters. One parameter is a scale or characteristic life parameter. For these plans and procedures, the value for this parameter need not be known; the techniques used are independent of its magnitude. A second parameter is a location or "guaranteed life" parameter. In these plans and procedures, it is assumed that this parameter has a value of zero and that there is some risk of item failure right from the start of life. If this is not the case for some applications, a simple modification in procedure is available. The third parameter, and the one of importance, is the shape parameter, β.[5] The magnitude of the conversion factors used in the procedures described in this report depends directly on the value for this parameter. For this reason, the magnitude of the parameter shall be known through experience with the product or shall be estimated from past research, engineering, or inspection data. Estimation procedures are available and are outlined in Ref (**1**).

4.6 For the common case of random chance failures with the failure rate constant over time, rather than failures as a result of "infant mortality" or wearout, a value of 1 for the shape parameter shall be assumed. With this parameter value, the Weibull distribution reduces to the exponential. Tables of conversion factors are provided in Annex A1 for 15 selected shape parameter values ranging from ½ to 10, the range commonly encountered in industrial and technical practice. The value 1, used for the exponential case, is included. Factors for other required shape parameter values within this range may be obtained approximately by interpolation. A more complete discussion of the relationship between failure patterns and the Weibull parameters can be found in Refs (**1-3**).

4.7 One possible acceptance criterion is the mean life for items making up the lot (μ). Mean life conversion factors or values for the dimensionless ratio $100t/\mu$ have been determined to correspond to or replace all the *p'* or percent defective values associated with Practice E2234 plans. In this factor, *t* represents the specified test truncation time and μ the mean item life for the lot. For reliability or life-length applications, these factors are used in place of the corresponding *p'* values normally used in the use of Practice E2234 plans for attribute inspection of other item qualities. The use of these factors will be demonstrated by several examples (see Sections 5, 7, and 9).

4.8 Annex Table 1A lists, for each selected shape parameter value, $100t/\mu$ ratios for each of the Practice E2234 AQL [*p'*(%)] values. With acceptance inspection plans selected in terms of these ratios, the probability of acceptance will be high for lots whose mean life meets the specified requirement. The actual probability of acceptance will vary from plan to plan and may be read from the associated operating characteristic curves supplied in MIL-STD-105. The curves are entered by using the corresponding *p'*(%) value. Annex Table 1B lists $100t/\mu$ ratios at the LQL for the quality level at which the consumer's risk is 0.10. Annex Table 1C lists corresponding $100t/\mu$ ratios for a consumer's risk of 0.05.

4.8.1 These ratios are to be used directly for the usual case for which the value for the Weibull location or threshold parameter (γ) can be assumed as zero. If γ is not zero but has some other known value, all that shall be done is to subtract the value for γ from *t* to get t_0 and from *m* to get m_0. These transformed values, t_0 and m_0, are then employed in the use of the tables and for all other computations. A solution in terms of m_0 and t_0 can then be converted back to actual or absolute values by adding the value for γ to each.

5. Examples, Mean Life Ratio

5.1 A Practice E2234 acceptance sampling inspection plan is to be applied to incoming lots of product for which the mean item life is the property of interest. An acceptable mean life of 2000 h has been specified, and under the plan, used lots with a mean life of this value or greater shall have a high probability of acceptance. A testing truncation time of $t = 250$ h has been specified. From past experience it has been determined that the Weibull distribution can be used as a life-length model and a shape parameter value of 2.5 and a location or threshold parameter value of 0 can be assumed. Single sampling is to be used. A sample of as many

[5] In some disciplines, the Weibull shape β parameter is referred to as the "Weibull slope."

as 300 items or so can be tested at one time. An appropriate sampling inspection plan shall be selected. Also, the consumer's risk under use of the selected plan shall be determined.

5.1.1 Computation of the $100t/\mu$ ratio at the AQL gives $100t/\mu = 100 \times 250/2000 = 12.5$. Examination of the ratios in the column for a shape parameter of 2.5 in Annex Table 1A discloses a value of 12.4 for an AQL of 0.40 in *p'*(%) terms. A plan with this AQL is accordingly to be used. Reference now to Practice E2234 indicates for Sample Size Code Letter M the sample size is 315; this value will accordingly be used. Examination of the Master Table for Normal Inspection (Single Sampling) in Practice E2234 shows for Sample Size Code Letter M and an AQL of 0.40, the acceptance number must be 3 and the rejection number 4.

5.1.2 The acceptance procedure will thus be to draw at random a sample of 315 items and submit them to life test for 250 h. At the end of that time, the number that has failed will be determined. If three items or less have failed, the lot will be accepted; if four or more have failed, it will be rejected.

5.1.3 The consumer's risk at a probability level of 0.10 can be determined by use of Annex Table 1B which gives $100t/\mu$ ratios at the LQL for the 0.10 risk value. For a shape parameter value of 2.5, a Sample Size Code Letter M, and an AQL of 0.40, the $100t/\mu$ ratio value is found to be 24. With $t = 250$, $100t/\mu = 24$ or $100 \times 250/\mu = 24$ which gives a value for μ of 1040. Thus, if the mean life for the items in the lot is 1040 h or less, the probability of acceptance will be 0.10 or less. If the lot quality for which the consumer's risk was 0.05 was desired instead, Annex Table 1C might be used which gives ratios at the LQL for this risk value.

5.2 A Practice E2234 plan with Sample Size Code Letter F and an AQL of 4.0 has been specified for a product for which life length in terms of cycles of operation is the quality of interest. Acceptance is to be in terms of a mean life evaluation. The Weibull distribution can be assumed to apply with a shape parameter value and a location parameter value of 0. Testing of sample items is to be truncated at 5000 cycles. The operating characteristics in terms of mean life for this plan are required.

5.2.1 Annex Table 1A lists ratios of $100t/\mu$ at selected AQLs and gives a $100t/\mu$ value of 0.62 for an AQL of 4.0 and a shape parameter value of ⅔. With $t = 5000$, $100t/\mu = 0.62$ or $100 \times 5000/\mu = 0.62$ which gives $\mu = 810\,000$. Therefore, if the mean item life for the lot is 810 000 or more, the probability of acceptance will be high. Annex Table 1C gives ratios $100t/\mu$ at the LQL for a consumer's risk of 0.05 and provides a $100t/\mu$ value of 14 for Code Letter F, an AQL of 4.0, and a shape parameter value of ⅔. Thus, $100 \times 5000/\mu = 14$ or $\mu = 36\,000$. If the mean item life for the lot is 36 000 cycles or less, the probability of acceptance will be 0.05 or less.

5.2.2 The sample size and acceptance number will be those specified by Practice E2234 for Code Letter F and an AQL of 4.0. For single sampling, the sample size will be 20 items and the acceptance number 2. For this example, as in all cases, the matched Practice E2234 double sampling and multiple sampling plans may be used instead. No additional changes in procedure are required. The specified test time, which in this case is 5000 cycles, shall be used for all samples.

5.3 Assume the Weibull distribution applies with a shape parameter value of $\beta = 3.33$ and a location or threshold parameter value, γ, of 3000 h. A Practice E2234 acceptance-inspection plan shall be selected under which the probability of acceptance will be low (0.05 or less) if mean item life is 8000 h or less. The sample size will be kept large to reduce the testing period time but it cannot exceed 250 items. To reduce further testing time, an acceptance number of 0 will be used. The required test truncation time must be determined; also, the AQL.

5.3.1 Reference to Practice E2234 indicates the Code Letter L with a sample size of 200 items shall be used. With this code letter and an acceptance number of 0, the AQL in Practice E2234 terms must be 0.065. Subtraction of the threshold parameter value, γ, of 3000 h from the required mean value, μ, of 8000 h gives as a converted value for the mean $\mu_0 = 8000 - 3000 = 5000$ h. This converted value must now be used in working with the tables of factors. Use of Annex Table 1C for $\beta = 3⅓$ Code Letter L, and an AQL of 0.065 gives a $100t/\mu$ value of 31 at the LQL (for $P(A) = 0.05$). With $\mu_0 = 5000$, $100t_0/\mu_0 = 100\ t_0/5000 = 31$ or $t_0 = 1550$ h. Conversion of this to absolute terms gives $t = t_0 + \gamma = 1550 + 3000 = 4550$ h as the required test truncation time.

5.3.2 From Annex Table 1A, the corresponding ratio at the AQL may be found. For an AQL of 0.065 and $b = 3⅓$ it is 12.3. Thus, $100\ t_0/\mu_0 = 12.3$ or $100 \times 1550/\mu_0 = 12.3$ or $\mu_0 = 12\,600$. Converting this to absolute terms gives $\mu = \mu_0 + \gamma = 12\,600 + 3000 = 15\,600$. Thus, the mean item life for a lot shall be 15 600 h or more for its probability of acceptance to be high.

6. Hazard Rate Conversion Factors

6.1 Another measure of lot quality is the hazard rate or instantaneous failure rate, *h(t)*, at some specified period of time, *t*. Hazard rate conversion factors or values for the dimensionless product $100t\{h(t)\}$ have been determined for all of the *p'* values that characterize the collection of Practice E2234 plans. As for the mean life plans, these products may be used in place of the corresponding *p'* values when using the Practice E2234 plans for life-length and reliability applications.

6.2 Annex Table 2A lists for each selected value for the shape parameter $100t\{h(t)\}$ products for each Practice E2234 AQL value. Annex Table 2B lists corresponding $100t\{h(t)\}$ products at the LQL for a consumer's risk of 0.10. Annex Table 2C lists products at the LQL for a consumer's risk of 0.05. Use of these tables of factors is similar to the method of use for the mean life ratios including the variation in method required when some nonzero value for the location or threshold parameter shall be assumed.

6.2.1 Note one point of difference. The products are for direct application only in cases in which the time *t* at which the hazard rate is specified or is to be evaluated is the same as the time *t* at which the life testing of sample items is to be truncated. However, a table of hazard rate ratios has been prepared, Annex Table 2D, to use in a simple modification of method that allows the test truncation time to differ from the time at which the hazard rate is specified. All that shall be done is to determine the hazard rate at the test truncation time which corresponds to the hazard rate at the specification time. Annex Table 2D provides ratios for making this conversion. It gives for various values of t_2 / t_1 the corresponding values for the ratio $h(t_2)/h(t_1)$ for all the shape parameter values for which conversion values have been provided. If the test truncation time is shorter than the time for hazard rate specification, t_1 is used to represent the test truncation time and $h(t_1)$ the corresponding hazard rate at that time. In this case, t_2 represents the time of hazard rate specification and $h(t_2)$ the specified hazard rate. If the test truncation is longer instead, the meanings given Subscripts 1 and 2 are simply reversed.

7. Examples, Hazard Rate

7.1 An acceptance-inspection plan shall be selected from the Practice E2234 collection for an application for which the Weibull distribution applies and for which it may be assumed the shape parameter value is 1.67 and the location parameter value is 0. A hazard rate of no more than 0.0005/h at 1000 h of life can be tolerated so a plan under which the probability of acceptance will be low (0.10) if this rate will be exceeded at this life is required. The test truncation time is likewise to be 1000 h.

7.1.1 Computation of the $100t\{h(t)\}$ product gives 100 × 1000 × 0.0005 = 50. Thus, apian shall be used for which this product is found at the LQL for which the consumer's risk is 0.10. Examination of the column for β = 1.67 in Annex Table 2B discloses several close possibilities. One is for a plan with Code Letter D and an AQL of 1.5 for which the product is 48; another is Code Letter F and an AQL of 4.0 for which the product is likewise 48; still another is Code Letter G and an AQL of 6.5 for which the product is 53. Any of these will provide fairly closely the required consumer's protection.

7.1.2 The last plan mentioned with its relatively large sample size and acceptance number will discriminate most sharply between good and bad lots and hence provide the most reasonable AQL. This will be achieved at the expense of a relatively large number of item hours of inspection, of course. With this choice (Code Letter G and an AQL of 6.5) the AQL can be easily determined. Reference to Annex Table 2A gives a value for $100t\{h(t)\}$ of 11.2 for an AQL of 6.5. Thus, 100 × 1000 $h(t)$ = 11.2 or $h(t)$ = 0.000 112 at t = 1000; the "acceptable" hazard rate is therefore 0.000 112 (per hour). If, alternatively, Code Letter D and an AQL of 1.5 had been used, the "acceptable" hazard rate would be 0.000 025 2 (per hour) instead.

7.2 Suppose the selected sampling plan must have an acceptable hazard rate (a rate for which the probability of acceptance is high) of 0.0001 per hour at 500 h of life. However, the testing of sample items shall be truncated at 200 h. A value of β = 0.67 and a location parameter of 0 can be assumed. A Practice E2234 plan shall be selected.

7.2.1 In this case, use Annex Table 2D. Letting t_2 = 500 and t_1 = 200, t_2/t_1 = 500/200 = 2.5. Referencing Annex Table 2D with this ratio using the value β = 0.67 column shows $h(t_2)/h(t_1)$ to be 0.734. With $h(t_2)=0.0001$, $0.0001/h(t_1)=0.734$, or $h(t_1)=0.000\,136$. This failure rate number shall be used in selecting the plan. Thus, $100t\{h(t)\}$ = 100 × 200 × 0.000 136 = 2.72 (note that the testing truncation time of 200 h is used as t at this point). Referencing Annex Table 2A examining the column for β = 0.67 shows that a Practice E2234 plan with an AQL of 4.0 % precisely meets this need.

8. Reliable Life Conversion Factors

8.1 A third possible reliability and life-length measure for the items in a lot or population is reliable life (ρ). Reliable life can be defined as the life beyond which some specified proportion of the items in the lot or population will survive. The letter r represents this specified proportion.

8.1.1 Tables of conversion factors have been prepared for two different proportions, r = 0.90 and r = 0.99. As for the mean life case, these reliable life conversion factors have been prepared in the form of values for the dimensionless ratio $100t/\rho$. Ratio values have been determined for all the $p'(\%)$ values associated with Practice E2234 plans. Annex Table 3A gives $100t/\rho$ values at each of the AQLs for r = 0.90; Annex Table 4A gives corresponding values for r = 0.99. Annex Table 3B gives ratio values at the LQL for a consumer's risk of 0.10 for r = 0.90; Annex Table 4B gives corresponding values for a consumer's risk of 0.10 and r = 0.99. Annex Table 3C gives ratio values at the LQL for a consumer's risk of 0.05 and r = 0.90; Annex Table 4C gives similar ratio values at a consumer's risk of 0.05 and r = 0.99. These conversion ratios are used in the same manner in which mean life ratios are used, including the manner for application when the location parameter is not zero. See Section 9 for an example.

9. Examples, Reliable Life

9.1 A sampling inspection plan shall be selected for a product for which item life in terms of feet of travel is the quality of interest. Experience indicates the Weibull distribution will serve well as a statistical model with a shape parameter value of approximately 1⅓ and a location parameter of 0. A lot will be considered "acceptable" if the reliable life is 40 000 ft and the probability of acceptance for such lots shall be high. For lots in which reliable life is 10 000 ft or less, the probability of acceptance shall be low, namely 0.05 or less. Reliable life is defined as the life beyond which 90 % of the items will survive; that is, r is to be 0.90. Testing of sample items is to be truncated at 5000 ft.

9.1.1 At the AQL, the $100t/\rho$ factor is 100 × 5000/40 000 = 12.5. Examination of Annex Table 3A shows that for β = 1⅓ the $100t/\rho$ ratio for an AQL of 0.65 is 12.4 which is quite close to the desired ratio. Accordingly, a plan with this AQL is to be adopted. At the unacceptable or LQL, the $100t/\rho_r$ factor is 100 × 5000/10 000 = 50. Referencing Annex Table 3C, which gives ratios at the LQL for $P(A)$ = 0.05, shows that, for Code Letter L, an AQL of 0.65 (which is required for this application, as indicated above) and β = 1⅓ the corresponding ratio is 48, which is close to the desired value of 50. Thus, a Practice E2234 plan with Code Letter

L and an AQL of 0.65 will meet the specified operating requirements. For single sampling, Practice E2234 shows the sample size to be 200 items and the acceptance number 3.

10. Summary

10.1 This practice preserves the structure of TR-7 for use in applications in which that standard is prescribed or its use is desirable.

10.2 This practice provides tables and procedures for applying three different measures of reliability in which testing is performed without replacement.

10.2.1 *Mean Life,* μ—The expected life of the product.

10.2.2 *Hazard Rate, h(t)*—The instantaneous failure rate at some specified time, t.

10.2.3 *Reliable Life,* ρ_r—The life ρ beyond which some specified proportion r of the items in the population will survive.

10.3 *Procedure for Application:*

10.3.1 Using the tables of factors provided in Annex A1, select a suitable sampling inspection plan from those tabulated in Practice E2234 for normal inspection.

10.3.2 Draw at random a sample of items of the size specified by the selected Practice E2234 plan.

10.3.3 Place the sample of items on life test for the specified period of time, t.

10.3.4 Determine the number of sample items that failed during the test period.

10.3.5 Compare the number of items that failed with the number allowed under the selected Practice E2234 plan.

10.3.6 If the number that failed is equal to or less than the acceptance number, accept the lot; if the number failing exceeds the acceptance number, reject the lot.

10.4 *Selection—Mean Life:*

10.4.1 Specify:

10.4.1.1 Acceptable mean life, μ_0.

10.4.1.2 Unacceptable mean life, μ_1.

10.4.1.3 Test truncation time, t.

10.4.1.4 Weibull shape parameter, β.

10.4.2 Compute the dimensionless ratio $100t/\mu_0$ from the specified μ_0 and t and enter Annex Table 1A under β. Locate the nearest value of $100t/\mu_0$ to that calculated and read the corresponding AQL.

10.4.3 Compute the dimensionless ratio $100t/\mu_1$ from the specified μ_1 and t and enter Annex Table 1B under β. Locate the nearest value of $100t/\mu_1$ corresponding to the AQL obtained in 10.4.2 and read the sample size code letter (use Annex Table 1C if a limiting quality with 5 % probability of acceptance is desired).

10.4.4 Obtain the sample size and acceptance number for the test from the Practice E2234 normal inspection plan.

10.4.5 *Mean Life Example:*

10.4.5.1 Suppose $\mu_0 = 50$, $\mu_1 = 10$, $t = 5$, $\beta = 1$, then $100t/\mu_0 = 10$ giving an AQL of 10 from Annex Table 1A and $100t/\mu_1 = 50$ giving Code F from Table 1B.

10.4.5.2 Practice E2234 gives sample size 20. Accept on 5 for Code F, AQL = 10.

10.5 *Selection—Hazard Rate or Reliable Life:*

10.5.1 The selection of plans for a specified hazard rate or reliable life follows the procedure for mean life described in 10.4 using appropriate dimensionless ratios and the associated tables from Annex A1.

10.5.2 Hazard rate uses the product $100t\{h(t)\}$ with the Annex A1 tables of Section B.

10.5.3 Reliable life uses the dimensionless ratio $100t/\rho$ with the Annex A1 tables of Section C.

11. Keywords

11.1 exponential distribution; hazard rate; mean life; MIL-STD-105; reliability; reliable life; Weibull distribution

ANNEX

(Mandatory Information)

A1. TABLES OF CONVERSION FACTORS

TABLE 1A

100t/μ Ratios at the Acceptable Quality Level (normal inspection)
for the ASTM E2234 Plans

NOTE—These plans assume the characteristic being measured has a Weibull distribution.

NOTE—Where scientific notation is used (that is, E-x), the decimal point is moved to the left x places (for example, if the number in scientific notation is 8.03E-04, then the decimal is moved to the left four places. The number in decimal notation is 0.000803).

AQL p'(%)	Shape Parameter, β														
	0.333	0.500	0.667	1.000	1.333	1.500	1.667	2.000	2.500	3.000	3.333	3.500	4.000	5.000	10.000
0.010	1.67E-11	5.00E-07	7.52E-05	1.00E-02	0.109	0.239	0.446	1.128	2.831	5.198	7.031	7.999	11.033	17.262	41.847
0.015	5.63E-11	1.13E-06	1.38E-04	1.50E-02	0.147	0.313	0.568	1.382	3.330	5.950	7.940	8.981	12.210	18.720	43.578
0.025	2.61E-10	3.13E-06	2.97E-04	2.50E-02	0.216	0.440	0.772	1.784	4.085	7.055	9.255	10.393	13.873	20.734	45.863
0.040	1.07E-09	8.00E-06	6.02E-04	4.00E-02	0.308	0.601	1.024	2.257	4.930	8.252	10.657	11.887	15.603	22.778	48.070
0.065	4.58E-09	2.11E-05	1.25E-03	6.50E-02	0.443	0.831	1.370	2.877	5.986	9.702	12.328	13.656	17.617	25.101	50.462
0.100	1.67E-08	5.01E-05	2.38E-03	0.100	0.612	1.108	1.774	3.569	7.113	11.200	14.030	15.445	19.622	27.360	52.684
0.150	5.64E-08	1.13E-04	4.38E-03	0.150	0.830	1.452	2.263	4.372	8.366	12.822	15.845	17.344	21.716	29.673	54.866
0.250	2.61E-07	3.13E-04	9.42E-03	0.250	1.218	2.042	3.076	5.645	10.265	15.205	18.472	20.072	24.677	32.868	57.744
0.400	1.07E-06	8.03E-04	1.91E-02	0.401	1.733	2.795	4.080	7.144	12.391	17.788	21.274	22.962	27.759	36.113	60.527
0.650	4.62E-06	2.13E-03	3.96E-02	0.652	2.497	3.867	5.464	9.112	15.055	20.922	24.619	26.388	31.352	39.806	63.547
1.000	1.69E-05	5.05E-03	7.58E-02	1.005	3.454	5.159	7.083	11.312	17.899	24.167	28.031	29.859	34.932	43.402	66.356
1.500	5.75E-05	1.14E-02	0.140	1.511	4.690	6.771	9.047	13.872	21.071	27.687	31.680	33.551	38.683	47.092	69.119
2.500	2.70E-04	3.20E-02	0.303	2.532	6.906	9.551	12.330	17.954	25.901	32.883	36.983	38.879	44.008	52.211	72.778
4.000	1.13E-03	8.33E-02	0.620	4.082	9.882	13.133	16.422	22.798	31.355	38.559	42.682	44.565	49.591	57.446	76.339
6.500	5.06E-03	0.226	1.311	6.721	14.362	18.311	22.149	29.253	38.275	45.530	49.569	51.388	56.174	63.469	80.242
10.000	1.95E-02	0.555	2.573	10.536	20.122	24.711	29.007	36.626	45.816	52.891	56.726	58.431	62.856	69.441	83.932

TABLE 1B

100t/μ Ratios at the Limiting Quality Level
for the ASTM E2234 Plans, Consumer's Risk = 0.10

NOTE—These plans assume the characteristic being measured has a Weibull distribution.

NOTE—Where scientific notation is used (that is, E-x), the decimal point is moved to the left x places (for example, if the number in scientific notation is 8.03E-04, then the decimal is moved to the left four places. The number in decimal notation is 0.000803).

Code Letter	AQL (p%)	Shape Parameter, β														
		0.333	0.50	0.667	1.000	1.333	1.500	1.667	2.000	2.500	3.000	3.333	3.500	4.000	5.000	10.000
A	6.500	25.433	66.274	92.927	115.129	120.933	121.682	121.789	121.073	119.240	117.369	116.235	115.707	114.281	112.025	106.605
B	4.000	7.536	29.455	50.583	76.753	89.223	92.861	95.489	98.856	101.388	102.531	102.922	103.050	103.265	103.299	102.369
C	2.500	1.628	10.604	23.509	46.052	60.826	66.059	70.282	76.573	82.650	86.478	88.298	89.056	90.885	93.267	97.271
C	10.000	11.235	38.440	61.762	87.681	98.590	101.478	103.429	105.659	106.932	107.183	107.115	107.045	106.759	106.086	103.741
D	1.500	0.397	4.142	11.616	28.782	42.756	48.289	53.012	60.537	68.485	73.938	76.686	77.865	80.809	84.899	92.805
D	6.500	2.361	13.587	28.313	52.129	66.752	71.750	75.709	81.469	86.852	90.126	91.644	92.267	93.745	95.608	98.484
D	10.000	7.688	29.850	51.091	77.265	89.669	93.274	95.871	99.185	101.658	102.759	103.128	103.247	103.437	103.437	102.437
E	1.000	9.26E-02	1.569	5.608	17.712	29.707	34.937	39.615	47.489	56.397	62.890	66.292	67.780	71.573	77.043	88.407
E	4.000	0.505	4.859	13.094	31.175	45.395	50.930	55.614	63.003	70.708	75.933	78.546	79.662	82.439	86.266	93.549
E	6.500	1.478	9.943	22.401	44.594	59.376	64.657	68.939	75.352	81.594	85.556	87.450	88.241	90.157	92.669	96.959
E	10.000	3.379	17.255	33.871	58.746	73.011	77.700	81.336	86.486	91.104	93.789	94.989	95.471	96.588	97.920	99.668
F	0.650	2.54E-02	0.663	2.939	11.513	21.505	26.215	30.592	38.287	47.470	54.478	58.255	59.930	64.265	70.683	84.679
F	2.500	0.133	1.992	6.709	19.962	32.495	37.836	42.562	50.415	59.160	65.448	68.714	70.136	73.745	78.908	89.471
F	4.000	0.369	3.940	11.189	28.073	41.963	47.492	52.224	59.786	67.805	73.325	76.114	77.312	80.306	84.476	92.574
F	6.500	0.795	6.577	16.430	36.267	50.850	56.335	60.899	67.954	75.120	79.860	82.193	83.182	85.617	88.916	94.975
F	10.000	2.566	14.362	29.516	53.596	68.156	73.089	76.980	82.608	87.821	90.964	92.410	93.001	94.398	96.140	98.758
G	0.400	6.21E-03	0.259	1.452	7.196	15.117	19.164	23.075	30.268	39.334	46.578	50.594	52.399	57.141	64.341	80.792
G	1.500	3.14E-02	0.763	3.266	12.352	22.670	27.474	31.911	39.657	48.825	55.770	59.498	61.147	65.405	71.684	85.277
G	2.500	8.46E-02	1.476	5.358	17.183	29.038	34.237	38.900	46.773	55.716	62.257	65.691	67.194	71.032	76.576	88.139
G	4.000	0.176	2.407	7.730	21.939	34.879	40.294	45.043	52.852	61.437	67.540	70.688	72.053	75.506	80.412	90.319
G	6.500	0.524	4.981	13.339	31.563	45.818	51.351	56.028	63.393	71.059	76.246	78.837	79.944	82.694	86.479	93.665
G	10.000	1.201	8.658	20.194	41.613	56.374	61.743	66.136	72.790	79.367	83.606	85.654	86.514	88.611	91.395	96.290
H	0.250	1.63E-03	0.106	0.743	4.605	10.817	14.232	17.654	24.215	32.904	40.140	44.254	46.126	51.108	58.847	77.265
H	1.000	8.09E-03	0.309	1.657	7.859	16.150	20.324	24.329	31.633	40.747	47.967	51.950	53.737	58.414	65.486	81.507
H	1.500	2.14E-02	0.590	2.694	10.865	20.592	25.223	29.548	37.194	46.384	53.437	57.252	58.947	63.342	69.869	84.191

TABLE 1B

100t/μ Ratios at the Limiting Quality Level
for the ASTM E2234 Plans, Consumer's Risk = 0.10

NOTE—These plans assume the characteristic being measured has a Weibull distribution.
NOTE—Where scientific notation is used (that is, E-x), the decimal point is moved to the left x places (for example, if the number in scientific notation is 8.03E-04, then the decimal is moved to the left four places. The number in decimal notation is 0.000803).

Code Letter	AQL (p%)	Shape Parameter, β														
		0.333	0.50	0.667	1.000	1.333	1.500	1.667	2.000	2.500	3.000	3.333	3.500	4.000	5.000	10.000
H	2.500	4.36E-02	0.950	3.849	13.783	24.613	29.558	34.081	41.892	51.014	57.846	61.487	63.093	67.223	73.274	86.217
H	4.000	0.125	1.912	6.505	19.555	31.996	37.320	42.039	49.898	58.675	65.000	68.290	69.724	73.366	78.583	89.286
H	6.500	0.273	3.222	9.621	25.385	38.912	44.411	49.164	56.852	65.130	70.906	73.850	75.121	78.311	82.793	91.647
H	10.000	0.680	5.928	15.199	34.432	48.908	54.418	59.030	66.212	73.575	78.490	80.922	81.956	84.512	87.997	94.483
J	0.150	3.97E-04	4.14E-02	0.367	2.878	7.603	10.404	13.316	19.143	27.264	34.319	38.434	40.330	45.442	53.568	73.718
J	0.650	1.95E-03	0.120	0.814	4.893	11.320	14.819	18.308	24.960	33.711	40.959	45.066	46.932	51.889	59.565	77.735
J	1.000	5.10E-03	0.227	1.316	6.738	14.390	18.342	22.183	29.290	38.314	45.569	49.606	51.425	56.210	63.501	80.262
J	1.500	1.03E-02	0.362	1.868	8.513	17.147	21.436	25.523	32.922	42.070	49.262	53.211	54.977	59.593	66.541	82.161
J	2.500	2.86E-02	0.717	3.117	11.974	22.148	26.911	31.322	39.046	48.222	55.196	58.946	60.607	64.899	71.240	85.013
J	4.000	6.09E-02	1.186	4.547	15.403	26.752	31.830	36.430	44.285	53.332	60.029	63.571	65.128	69.116	74.920	87.180
J	6.500	0.145	2.119	7.025	20.584	33.251	38.618	43.353	51.194	59.891	66.120	69.349	70.753	74.312	79.393	89.745
J	10.000	0.354	3.832	10.956	27.682	41.525	47.051	51.787	59.369	67.426	72.984	75.795	77.003	80.026	84.240	92.444
K	0.100	1.04E-04	1.70E-02	0.188	1.842	5.440	7.726	10.188	15.315	22.807	29.575	33.618	35.502	40.645	48.994	70.500
K	0.400	5.08E-04	4.88E-02	0.415	3.124	8.086	10.989	13.988	19.945	28.174	35.270	39.392	41.287	46.384	54.454	74.325
K	0.650	1.32E-03	9.21E-02	0.669	4.292	10.261	13.580	16.925	23.378	31.991	39.210	43.330	45.209	50.217	58.025	76.724
K	1.000	2.64E-03	0.146	0.947	5.410	12.206	15.845	19.445	26.246	35.094	42.354	46.445	48.299	53.208	60.774	78.520
K	1.500	7.24E-03	0.287	1.568	7.573	15.707	19.828	23.793	31.052	40.147	47.378	51.376	53.170	57.875	65.002	81.205
K	2.500	1.52E-02	0.470	2.270	9.692	18.900	23.373	27.590	35.129	44.311	51.439	55.323	57.054	61.558	68.290	83.234
K	4.000	3.54E-02	0.825	3.465	12.849	23.351	28.206	32.675	40.447	49.602	56.509	60.206	61.840	66.054	72.252	85.614
K	6.500	8.31E-02	1.459	5.312	17.084	28.913	34.105	38.765	46.638	55.588	62.137	65.577	67.084	70.929	76.488	88.088
K	10.000	2.51E-01	3.050	9.234	24.700	38.122	43.608	48.363	56.079	64.420	70.262	73.247	74.535	11.111	82.341	91.396
L	0.065	2.54E-05	6.63E-03	9.29E-02	1.151	3.824	5.648	7.684	12.107	18.898	25.286	29.197	31.041	36.139	44.598	67.263
L	0.250	1.24E-04	1.90E-02	0.205	1.950	5.677	8.025	10.541	15.756	23.331	30.141	34.196	36.083	41.226	49.553	70.902
L	0.400	3.19E-04	3.58E-02	0.329	2.675	7.196	9.907	12.742	18.454	26.476	33.490	37.597	39.493	44.616	52.787	73.179
L	0.650	6.35E-04	5.66E-02	0.465	3.366	8.550	11.548	14.627	20.701	29.026	36.156	40.281	42.174	47.255	55.271	74.880
L	1.000	1.73E-03	0.110	0.766	4.696	10.977	14.419	17.863	24.453	33.163	40.403	44.515	46.386	51.360	59.079	77.417
L	1.500	3.58E-03	0.179	1.103	5.991	13.176	16.961	20.673	27.619	36.556	43.819	47.889	49.728	54.583	62.027	79.325
L	2.500	8.23E-03	0.312	1.671	7.903	16.218	20.400	24.411	31.722	40.838	48.057	52.038	53.823	58.497	65.560	81.553
L	4.000	1.89E-02	0.544	2.536	10.435	19.977	24.552	28.840	36.450	45.640	52.722	56.562	58.270	62.705	69.307	83.851
L	6.500	5.50E-02	1.109	4.323	14.892	26.083	31.122	35.699	43.544	52.617	59.357	62.931	64.503	68.535	74.416	86.887
M	0.040	6.51E-06	2.67E-03	4.70E-02	0.731	2.720	4.172	5.851	9.647	15.758	21.733	25.477	27.263	32.259	40.725	64.276
M	0.150	3.15E-05	7.65E-03	0.103	1.237	4.035	5.924	8.022	12.549	19.448	25.897	29.831	31.683	36.792	45.242	67.747
M	0.250	8.12E-05	1.44E-02	0.166	1.695	5.111	7.309	9.692	14.691	22.061	28.766	32.789	34.668	39.808	48.185	69.916
M	0.400	1.61E-04	2.27E-02	0.234	2.131	6.069	8.515	11.119	16.472	24.176	31.047	35.120	37.011	42.153	50.443	71.535
M	0.650	4.36E-04	4.40E-02	0.385	2.968	7.780	10.619	13.564	19.440	27.601	34.672	38.790	40.686	45.793	53.898	73.944
M	1.000	8.99E-04	7.14E-02	0.553	3.779	9.326	12.474	15.679	21.935	30.402	37.580	41.706	43.593	48.643	56.566	75.753
M	1.500	2.05E-03	0.124	0.834	4.970	11.454	14.975	18.481	25.157	33.924	41.174	45.279	47.143	52.093	59.753	77.857
M	2.500	4.65E-03	0.214	1.257	6.537	14.066	17.975	21.782	28.849	37.852	45.110	49.157	50.981	55.785	63.117	80.019
M	4.000	1.32E-02	0.429	2.120	9.260	18.265	22.674	26.846	34.338	43.511	50.664	54.572	56.316	60.861	67.671	82.856
N	0.025	1.63E-06	1.06E-03	2.35E-02	0.461	1.923	3.066	4.435	7.657	13.099	18.631	22.180	23.891	28.740	37.130	61.374
N	0.100	7.87E-06	3.03E-03	5.17E-02	0.779	2.852	4.352	6.078	9.957	16.162	22.197	25.965	27.760	32.774	41.243	64.684
N	0.150	2.02E-05	5.69E-03	8.29E-02	1.067	3.611	5.367	7.340	11.654	18.329	24.651	28.535	30.370	35.455	43.922	66.751
N	0.250	4.01E-05	8.98E-03	0.117	1.340	4.286	6.250	8.418	13.063	20.082	26.600	30.558	32.418	37.538	45.974	68.293
N	0.400	1.08E-04	1.74E-02	0.191	1.864	5.490	7.788	10.261	15.407	22.917	29.694	33.739	35.624	40.767	49.111	70.585
N	0.650	2.22E-04	2.81E-02	0.275	2.371	6.574	9.142	11.853	17.374	25.229	32.171	36.262	38.156	43.292	51.530	72.302
N	1.000	5.03E-04	4.84E-02	0.413	3.113	8.063	10.961	13.956	19.908	28.132	35.226	39.347	41.242	46.340	54.413	74.297
N	1.500	1.13E-03	8.34E-02	0.621	4.083	9.883	13.135	16.425	22.801	31.358	38.562	42.685	44.568	49.594	57.448	76.341
N	2.500	3.18E-03	0.166	1.040	5.759	12.791	16.519	20.188	27.078	35.982	43.245	47.324	49.169	54.046	61.538	79.012
P	0.015	3.97E-07	4.14E-04	1.16E-02	0.288	1.352	2.241	3.345	6.054	10.854	15.929	19.263	20.889	25.554	33.799	58.556
P	0.065	1.92E-06	1.18E-03	2.55E-02	0.487	2.004	3.181	4.583	7.871	13.390	18.975	22.548	24.269	29.138	37.540	61.712
P	0.100	4.93E-06	2.22E-03	4.09E-02	0.666	2.537	3.922	5.534	9.209	15.183	21.071	24.777	26.548	31.519	39.975	63.682
P	0.150	9.76E-06	3.50E-03	5.76E-02	0.837	3.010	4.565	6.345	10.321	16.633	22.734	26.530	28.335	33.367	41.840	65.150
P	0.250	2.62E-05	6.76E-03	9.43E-02	1.163	3.853	5.686	7.731	12.169	18.975	25.372	29.285	31.130	36.230	44.688	67.331
P	0.400	5.38E-05	1.09E-02	0.135	1.478	4.612	6.671	8.926	13.717	20.883	27.481	31.468	33.336	38.467	46.882	68.964
P	0.650	1.21E-04	1.88E-02	0.203	1.938	5.652	7.992	10.503	15.708	23.275	30.080	34.134	36.021	41.164	49.493	70.859
P	1.000	2.73E-04	3.22E-02	0.304	2.538	6.919	9.567	12.349	17.977	25.928	32.911	37.012	38.908	44.037	52.238	72.797
P	1.500	7.58E-04	6.37E-02	0.507	3.570	8.937	12.010	15.153	21.321	29.718	36.874	41.000	42.891	47.957	55.926	75.323
Q	0.010	1.04E-07	1.70E-04	5.95E-03	0.184	0.967	1.665	2.559	4.843	9.080	13.728	16.849	18.388	22.856	30.913	56.000
Q	0.040	5.03E-07	4.85E-04	1.31E-02	0.311	1.434	2.362	3.506	6.296	11.200	16.351	19.721	21.362	26.060	34.333	59.017
Q	0.065	1.29E-06	9.08E-04	2.09E-02	0.426	1.815	2.912	4.233	7.366	12.699	18.155	21.669	23.367	28.188	36.558	60.899
Q	0.100	2.55E-06	1.43E-03	2.94E-02	0.535	2.153	3.389	4.852	8.254	13.910	19.587	23.201	24.938	29.839	38.262	62.302
Q	0.150	6.85E-06	2.76E-03	4.82E-02	0.743	2.755	4.220	5.911	9.729	15.865	21.856	25.607	27.395	32.396	40.863	64.385
Q	0.250	1.40E-05	4.46E-03	6.90E-02	0.944	3.296	4.949	6.823	10.965	17.458	23.670	27.512	29.332	34.392	42.865	65.943
Q	0.400	3.16E-05	7.66E-03	0.104	1.237	4.037	5.926	8.025	12.552	19.452	25.902	29.836	31.688	36.797	45.247	67.751
Q	0.650	7.08E-05	1.31E-02	0.155	1.619	4.939	7.090	9.430	14.359	21.661	28.332	32.343	34.219	39.356	47.747	69.597