Recommendation T/N 45-01 (Edinburgh 1988)

TESTING THE COMPLIANCE OF AN EQUIPMENT WITH ITS RELIABILITY, MAINTAINABILITY AND AVAILABILITY SPECIFICATIONS

Recommendation proposed by Working Group T/WG 14 "Network Aspects" (NA)

Text of the Recommendation adopted by the "Telecommunications" Commission:

"The European Conference of Postal and Telecommunications Administrations,

considering

— that for various equipments, besides the normal functional aspects, availability, reliability and maintainability aspects are specified,

— that when accepting these equipments from the manufacturer or deliverer, the Administrations must be sure that these availability, reliability and maintainability specifications are met,

— that it is therefore advisable to use testing methods, most of which are based on statistical elaboration of various information in this field; which methods must be agreed with the manufacturer or deliverer of the equipment concerned,

— that this subject remains the total responsibility of the Administration concerned, i.e. this Recommendation will not dictate what the Administration should or should not do in this matter,

— that it is, however, recommendable to have some guidance on the matter of testing the compliance of the specified reliability, maintainability and availability aspects,

recommends

the following guidance, which describes a method for testing the compliance of an equipment with its reliability, maintainability and availability specifications."

1. INTRODUCTION

This Recommendation is made of three parts:

- the first part indicates the application area of the Recommendation by listing reliability, maintainability, availability characteristics to which the Recommendation applies;
- the second part introduces three testing principles which can be used for testing the compliance of an equipment to its reliability, maintainability, or availability specifications and indicates for each principle to which characteristic it is best fitted;
- the third part is devoted to the description of methods and mathematical tools referrenced in the second part.

2. CHARACTERISTICS TO BE VERIFIED

The following list gives the main reliability, maintainability and availability characteristics for which a method for compliance testing is proposed in this Recommendation.

2.1. Reliability characteristics

2.1.1. *Global failure rate*

This parameter is used to evaluate the number of repairs which will have to be done, for a given period, on the considered equipment.

2.1.2. *Functional failure rate*

This parameter is used to evaluate the number of times when one equipment is not able to work as specified during a given period.

For a switching system, several functional failure rates can be spedified according to the consequence of the considered failure:

- failure affecting a given group of subscribers;
- failure affecting a given group of circuits;
- failure which do not affect specifically a given group of subscribers or circuits but which lower the trafficability performance of the system.

2.2. Maintainability characteristics

2.2.1. *Probability of failed state detection*

It is the probability that the existence of a failure inside the equipment is detected, whether the required functions of the equipment are fulfilled or not.

2.2.2. *Efficiency of localization of a failed item*

When a failure is detected, a localization procedure takes place which will identify a given set of presumably failed items as a failure localization.

The efficiency of the localization procedure is defined by two probabilities corresponding to the following definition:

For precise localization, where no more than k items should be identified per failure ($k=1$ in most applications), a probability P1 is specified. However, as localization procedures cannot be perfect, a larger set (between $k+1$ and, say, m items) can be identified, but with low probalility P2 (consequently, the probability that the number of identified items per failure is more than m is equal to $1-(P1+P2)$).

In summary, the efficiency of localization is defined by the two probabilities P1 and P2 such that:
$P1=P$ (localization among 1 or 2 or ... k items)
$P2=P$ (localization among $k+1$, or $k+2$, ... or m items)
with $m<n$, n being the total number of items building the equipment.

2.2.3. *Durations related to the intrinsic maintainability of the equipment*

These durations (failed state detection time, failure correction time...) react on the value of the availability of the equipment: they can be specified directly of indirectly through the specification of the intrinsic availability of the equipment.

2.3. Availability characteristics

The unavailability of an equipment can be complete or partial.

Complete unavailability is related to the complete failure of the equipment.

For a switching system, several partial unavailabilities can be specified, depending on the consequence of the failures, as for the functional failure rate.

3. METHODS FOR TESTING

3.1. Testing from field data

The method consist in estimating the characteristic to be verified from field data collected on one (or several) equipment(s) and in using statistical tools to process the collected data so as to decide (with previously accepted risks) whether the equipment complies or not with its specifications.

This method applies particularly to the test of the global failure rate of equipments.

It can be chosen only if the quantity of data which can be collected during field operation is of a magnitude compatible with the use of the statistical tests proposed in paragraph 4.

3.2. Testing from predictions

When testing from field data cannot be considered, it is possible to test the compliance of an equipment to its reliability or availability specifications by comparing the specified value of each characteristic to the corresponding value obtained from a prediction.

This method must be chosen when the quantity of field data which could be collected during field testing is so low that significant conclusions could not be drawn from them.

It applies particularly to the test of the global failure rate (when field testing appears impossible) and to the test of functional failure rates and of availability characteristics.

It is recommended to present the previsions as indicated in paragraph 4.2.

Remark. As the functional failure rate and the availability characteristics depend on the mean values of durations which are intrinsic to the equipment (failed state detection time, failure correction time...), it is necessary to test that the values adopted for these mean durations in the prediction are consistent with the actual possibilities of the equipment: the corresponding test can be made by failure simulation (as indicated in paragraph 3.3.) to collect data on the considered durations, followed by statistical tests on the mean values (as described in paragraph 4.6.).

3.3. Test by failure simulation

The method consists in simulating failure located in the different parts of the equipment in quantities which reflect the mean number of failures which are likely to occur in field operation in that part of the equipment.

This method is particularly adapted to the test of maintainability parameters. As a matter of fact, these parameters are difficult to predict and their field testing may be long and hasardous. So, testing by failure simulation applies particularly to the test of failed state detection probability, of localization efficiency and to the test of mean durations related to the maintainability of the equipment.

The method to select the failures to be simulated is described in paragraph 4.3.

The statistical test for the failed state detection probability is described in paragraph 4.4.

The statistical test for the efficiency of localization of a failed item is described in paragraph 4.5.

The statistical test for the mean durations taken in to account in the computations of functional failure rates or in the computations of unavailability characteristics is described in paragraph 4.6.

SUMMARY TABLE

Characteristic to be tested	Recommended test method	Remarks
Global failure rate	Field testing	(1)
	Prediction	
Functional failure rate	Prediction	(2)
Probability of failed state detection	Failure simulation	
Efficiency of failed item localization	Failure simulation	
Unavailability	Prediction	(2)

(1) Under the condition that the quantity of failures likely to occur is consistant with the quantities required for statistical testing (see paragraph 4.).

(2) It can be necessary, according to the situation, to test that the mean values of the actual "repair" times are consistent with the values adopted in the prevision (for the durations which are intrinsic to the systems).

4. METHODS AND MATHEMATICAL TOOLS

4.1. Test of a failure rate from field data

4.1.1. *Data collection*

It is recommended that reliability data be collected according to a systematic method of collection and that this method be well known from operating people.

For this, see CCITT Handbook on the quality of service and network maintenance, chapter 4, section 8 and revised IEC 362 Publication (in preparation).

4.1.2. *Failures of the equipment or system*

Each test item failure shall be classified as a relevant or a non-relevant failure. All test item failures that cannot be clearly classified as non-relevant failures according to sub-clauses 4.1.2.1., 4.1.2.2., 4.1.2.3. below or to any additional rule given in the detailed reliability test specification shall be considered relevant test item failures.

If two or more independent failure causes are present, each of these shall be considered as one test item failure.

A test item failure may be regarded as a non-relevant failure only if the circumstances at the occurrence show clear evidence to classify it into one of the classes defined in sub-clauses 4.1.2.1., 4.1.2.2., or 4.1.2.3. below. The evidence shall be documented and included in the test report.

Additional classes of non-relevant failures applicable in a particular case may be defined in the detailed reliability test specifications.

4.1.2.1. Secondary failures

A secondary failure is defined as a failure of an item caused either directly or indirectly by the failure of another item.

Secondary failures are considered non-relevant. The corresponding primary failure is always a relevant failure if it is located in the test item. Observe that a secondary failure may occur after a time delay from the occurrence of the primary failure. The duration of the time delay shall be approved by the customer or test agency. However, secondary failures can be useful for the classification of failures in terms of safety aspects, costs of failure, etc.

4.1.2.2. Misuse failures

A misuse failure is defined as a failure attributable to the application of stresses beyond the stated capabilities of the item.

Misuse failures during field testing may be due to unintentional operating conditions, e.g. operating conditions exceeding those specified for the equipment (lightning), rough handling by operating or repair personnel, etc. Misuse failures are considered non-relevant.

4.1.2.3. Failure eliminated by design correction

A type of failure observed early in the test may result in a design change or other remedy implemented on all equipments in the population. If such a corrective action is proven to be effective, the failures of this type may be reclassified as non-relevant failures upon agreement.

4.1.3. *Test plans*

In the following test plans, the failure rate is supposed to be constant.

These plans are based on a parametric hypothesis test which consists in opposing the following hypothesis:
— the true failure rate λ is equal to the specified value λ_0,
— the true failure rate λ is equal to the maximum acceptable value λ_1.
Such a statistical test involves the following false decision risks:
α: Suppliers risk: it is the probability of rejection of an equipment or system (or of a batch) whose true failure rate λ is equal to the specified value λ_0 (the probability of rejection when $\lambda < \lambda_0$ is less than α).

β: Administration's risk: it is the probability of acceptance of an equipment or system (or of a batch) whose true failure rate λ is equal to the maximum acceptable value λ_1 (the acceptance probability when $\lambda > \lambda_1$ is less than β).

The ratio $D = \lambda_1/\lambda_0$ is called the discrimination factor.

4.1.3.1. Standard test plans

When the values of α, β, λ_0 and D are given, one can derive the operating test time (T) which has to be accumulated by the equipments or systems and the maximum number (C) of failures occurring during the accumulated test time T compatible with the decision that the equipment complies with its failure rate specification.

Corresponding test plans are described in IEC 605-7 Publication.

4.1.3.2. Other test plans

It can be convenient to choose beforehand the value of the accumulated test time T (which allows to decide beforehand of the quantity of equipments or systems to be monitored and of the duration of the test).

In this case, α, β, λ_0 and T are given and the value of the discrimination factor (D) as well as the maximum number (C) of failures which can occur during the accumulated test time T are derived.

The method for deriving D and C from the values of α, β, λ and T is given in the supplement to the IEC 605-7 Publication: "Procedure for the design of time terminated test plans", to be published.

4.2. Presentation of reliability, maintainability and availability predictions

4.2.1. *Related documents*

The presentation of reliability, maintainability and availability predictions is covered by the IEC 863 Publication. However, some necessary adaptations have been made in the following paragraphs.

4.2.2. *Object*

The object of this document is to provide the writer of a prediction report with a complete listing of all items to be considered in making a proper and full presentation of prediction information.

In this Recommendation, the way of presentation is intended to facilitate compliance testing of reliability, maintainability and availability characteristics by comparing the specified values of the required characteristics to the correponding predicted values.

4.2.3. *Application area*

This Recommendation is generally applicable to all reliability, maintainability and availability predictions of telecommunication equipment or systems, including hardware, software and human elements.

4.2.4. *Contents of the presentation*

According to IEC 863 Publication.

4.2.5. *Detail requirements of the presentation*

For the detail requirements of the presentation, refer to IEC 863 Publication, except for the following:

4.2.5.1. Characteristics

The system or equipment reliability, maintainability and availability characteristics which constitute the final objective of the prediction shall be stated by reference to relevant system or equipment documents, such as specifications of reliability, maintainability and availability requirements.

4.2.5.2. Assumptions, definitions and conditions

All the assumptions, definitions and conditions necessary for the prediction shall be stated:

System/equipment functions. A system or equipment may be intended to function in many modes or to carry out sequences of functions. Any such function or sequence of functions, covered by the prediction, shall be stated. Any function or equipment excluded from the prediction shall be identified and the reason given.

Failure definitions. The failures of the system/equipment to be considered in the prediction are those stated in the reliability/availability specification of the equipment/system. Any deviation from these definitions shall be clearly indicated.

Quality/reliability programme. The quality and maturity of the system or equipment shall be stated, for instance, in terms of:

a) system or equipment burn-in;
b) reference to quality/reliability programme of system or equipment and components;
c) component screening.

Any assumption regarding reliability or maintainability growth shall be stated.

Environmental conditions. The environmental conditions for which the prediction is performed shall be those specified for the equipment/system operation.

Operational conditions. The operational conditions for which the prediction is performed shall be those stated for the equipment/system in its relevant specification.

Definition of maintenance actions. The equipment/system specification defines as maintenance requirements on which equipment/system complexity level corrective maintenance is to be performed, such as failure localization of replaceable units or failure localization down to component level.

Accordingly, the expected mean values of the durations of the corresponding maintenance actions, when used for the prediction, shall be stated (see paragraph "Maintainability data").

Preventive maintenance conditions. The preventive maintenance conditions for which the prediction is performed shall be stated in the form of:
a) categories and standards of preventive maintenance resources;
b) categories of preventive maintenance actions;
c) criteria governing the scheduling of preventive maintenance, for example fixed intervals between actions or degree of wear-out;
d) effects on system operational readiness.

Corrective maintenance resources. Categories and standards of corrective maintenance resources shall be defined. These may include:
a) replacement units;
b) spare components;
c) software media;
d) test equipment;
e) tools;
f) test programs;
g) documentation;
h) personnel.

Maintenance support conditions. The maintenance support conditions for which the prediction is performed shall be in accordance with those stated by the Administration in the equipment/system specification.

4.2.5.3. Analysis

An analysis has to be made to determine:
a) the structure of the system/equipment;
b) the stresses applied to the system/equipment and its parts;
c) the maintainability properties of the system/equipment;
d) the properties of the maintenance support.

Based on this analysis models are built for:
— the reliability structure,
— the maintainability structure,
— the availability structure.

The mathematical model used for each characteristic and the derivation of applied formulas shall be stated or referenced.

If the prediction is performed by a procedure which preceeds stepwise through several functional levels of the system/equipment, the mathematical models uses shall be presented separately for each characteristic.

4.2.5.4. Data sources

Reliability data. The sources of reliability data shall be agreed by the Administration.

Reliability data used, such as failure rates or mean times between failures at unit level, shall be stated.

Maintainability data. Maintainability data used, such as mean active repair times at different levels, failure detection probability, failure localization efficiency, shall be stated.

Maintenance support data. Maintenance support data used, such as numbers of repair men and spare parts, shall be stated either directly or in probabilistic terms. They shall be consistent with the maintenance support conditions.

4.2.5.5. Prediction results

The numerical results shall be clearly presented for each specified characteristic, in correspondence with the corresponding required value.

4.3. Failure simulation

Failure simulation is merely used for testing maintainability related parameters.

4.3.1. *Quantity of failures to be simulated*

The total number of failures to be simulated shall be determined from the adequate test plan (paragraphs 4.4., 4.5. or 4.6.).

4.3.2. *Distribution of failures*

For each group of components belonging to a given family (transistor, integrated circuits) and belonging to a given part of the equipment, the number of simulated failures shall be proportional to the mean number of failures which are likely to occur in field operation among the components of this group. When the failure rates of the components are constant, the number of failures to simulate in each component is proportional to its failure rate: the following paragraphs give the details of the method according to this hypothesis.

The failure rates to be used in this respect are to be agreed upon by the supplier and by the Administration.

4.3.3. *Application*

a) Classify the p parts of the equipment in decreasing order according to the sum λ_p of the failure rates of their components.

b) Classify the q families of components in decreasing order according to the sum Λ_q of the failure rates of their components in each family.

c) Give to each group "family of type q belonging to part p" a weight $\frac{\lambda_{pq}}{\Lambda}$ where:

λ_{pq} is the sum of the failure rates of the components belonging to the group pq.
Λ is the sum of the failure rates of all the components of the equipment.

A table as the following one summarises the tasks a), b) and c) above.

Component family	$\sum_p \lambda_{pq}$ per family	Equipment parts				
		1	2	3	.....	P
1	1_1	λ_{11}	λ_{21}	λ_{31}	.....	λ_{p1}
2	1_2	λ_{12}	λ_{22}	λ_{32}		λ_{p2}
.....						
q	Λ	λ_{1q}	λ_{2q}	λ_{3q}		λ_{pq}

d) Determine for each group (case pq of the table) the number n pq of failures to be simulated. If N is the total number of failures to be simulated, n pq is given by:

$$n\ pq = N \times \frac{\lambda_{pq}}{\Lambda}$$

with $\Lambda = \Lambda_1 + \Lambda_2 + \dots \Lambda_2$
and $\Lambda_q = \Lambda_{1q} + \Lambda_{2q} + \lambda_{pq}$

The computations generally lead to non-integer values of n pq. These figures will be systematically rounded to the nearest lower integer, thus leading for certain cases to zero. Thus, over the N failures to be simulated, some remain being not assigned: the pq groups in which a remaining failure will be simulated will be chosen at random among those for which n pq < 1.

e) Select at random among the components of each group the n pq ones for which a failure will be simulated.

Remark. The choice of the failure modes for each component shall be guided by the distribution of the failure modes of the family to which the component belongs, when this distribution is known.

4.4. **Test of success (failure) ratios**

4.4.1. *Principle*

This test is based on the properties of the binomial law and is intended, in this Recommendation, to the test of the failed state detection probability.

It consists in recording the results of N failures simulations and in comparing the observed number r of times where the failure is not detected to a decision criteria rRE.

One concludes the the equipment complies with its specification if $r < rRE$ and that it does not comply with its specification if $r \geqslant rRE$.

The failures to be simulated shall be distributed inside the equipment according to the method of paragraph 4.3.

This test involves the following two false decision risks:

— to risk α of the supplier is the probability that $r \geqslant rRE$ even when the true (but unknown) percentage of success p characterising the equipment is equal to the specified value P0;

— the risk β of the Administration is the probability that $r < rRE$ even when the true percentage of success p characterising the equipment is equal to the minimum acceptable value P1 defined as $1 - P1 = D (1 - P0)$ where D is called the discrimination factor.

In the test plans described below, the risks α and β are equal.

4.4.2. *Standard test plans*

When the values of $\alpha = \beta$, P0 and D are given, one derives the number N of simulations to be performed as well as the decision criteria rRE.

The corresponding test plans are described in IEC 605-5 Publication.

4.4.3. *Other test plans*

It can be convenient to decide beforehand of the total quantity of simulations to be performed.

In this case, $\alpha = \beta$, P0 and N are given and one derives the values of D and rRE.

The method for deriving the values of D and rRE from the values of $\alpha = \beta$, P0 and N is given in Appendix 1.

4.5. **Test of the efficiency of localization of a failed item**

The following statistical test is intended to test the compliance of an equipment to its specification of efficiency of localization of failed unit expressed as two probabilities P1 and P2, for which the values p1 and p2 are required:
P1 = P (localization among 1, or 2 or ... k items)
P2 = P (localization among k + 1 or k + 2 or m items)
with m < n, n being the total number of items building the equipment

4.5.1. *Principle*

This test is based on the properties of the multinominal distribution.
It consists in testing the hypothesis H0:
P1 = p1, P2 = p2, p1 and p2 being the required values
against the hypothesis H1:
P1 = q1, P2 = q2, q1 and q2 being minimum acceptable values

4.5.2. *Performing the test*

a) Perform the N failure simulations, the simulated failures being distributed according to paragraph 4.3.

b) Record the quantities:
X1 = number of successful localizations within 1 or 2 or ... k items
X2 = number of successful localization within k + 1 or k + 2 or ... m items

c) Compute the quantities A1 and A2 from the values of p1, p2, q1, q2 by (ℓ_n = Nepriam logarithm):

$$A1 = \ell_n \frac{(p1)}{q1} - \ell_n \frac{(1 - p1 - p2)}{1 - q1 - q2}$$

$$A2 = \ell_n \frac{(p2)}{q2} - \ell_n \frac{(1 - p1 - p2)}{1 - q1 - q2}$$

d) Compare the quantity A1X1 + A2X2 to a criteria C: If A1X1 + A2X2 ⩾ C, the H0 hypothesis can be admitted and then one considers that the equipment complies with its specification of failed item localization efficiency.

If A1X1 + A2X2 < C, one considers that the equipment does not comply with its specification of failed item localization efficiency.

As any statistical test, this test involves the following false decision risks:
— the risk α of the supplier is the probability that A1 + A2X2 < C, i.e. one concludes that the equipment does not comply to its specification of failed item localization efficiency, even when the H0 hypothesis is true, which means that P1 = p1 and P2 = p2 (specified values);
— the risk β of the Administration is the probability that A1X1 + A2X2 ⩾ C, i.e. one concludes that the equipment complies with its specification of failed item localization efficiency, even when the H1 hypothesis is true which means that the failed item localization is caracterised by the minimum acceptable values q1 and q2.

The risks α and β are generally equal.

4.5.3. *Quantity of tests to be performed*

(Under study.)

4.5.4. *Decision criteria*

(Under study.)

4.6. **Test of mean durations**

The statistical test described below does not need any hypothesis on the distributions of the durations.
In this test, the mean values $\bar{x}$ of n observed durations is compared to a decision criteria L.
One concludes that the true mean value of the considered durations is less than or equal to the value m0 proposed by the supplier, as a basis for availability computations, if $\bar{x} > L$.
This test involves two risks of false conclusions:
— the risk α of the supplier is the probability that $\bar{x} > L$, even when the true mean m of the considered durations is equal to the value m0 so that one concludes wrongly that the equipment does not comply with the value taken into account in the computations of functional failure rate or of availability;
— the risk β of the Administration is the probability that $\bar{x} \leqslant L$, even when the true mean m of the considered durations is equal to a value m1 = D × m0 so that one concludes wrongly that the equipment complies with the value taken into account in the computations, D being the discrimination factor.

4.6.1. *Quantity of observations required*

The test is based on the central limit theorem and requires a minimum of 30 observations.
On the other hand, the number N of observations is related to the risks α and β by:

$$N = \frac{4\ u^2\ \sigma^2}{(m1 - m0)^2}$$

where $\begin{cases} u \text{ is the unit normal variable: } u = u_{1-\alpha} = -u^{\beta} \\ \sigma^2 \text{ is the (unknown) variance of the durations } m_1 = D\ m_0 \end{cases}$

For the test of the durations proposed by the supplier, the value D = 2 will be admitted.

* If an estimation of σ, say $\hat{\sigma}$ is available, one computes the quantity of observations required from:

$$N = \frac{4\ u^2\ (\hat{\sigma})^2}{m_0^{\ 2}}$$

* If no information is available on the variance of the durations, one executes the 30 first observations, from which one computes the observed variance $(S_{30})^2$ and the quantity of observations to be performed is obtained from:

$$N = \frac{4\ u^2\ (S_{30})^2}{m_0^{\ 2}}$$

4.6.2. *Decision criteria*

The decision criteria L is given by:

$$L = m0 + u\ \frac{S_N}{\sqrt{N}}$$

S_N being the standard deviation of the N observed duration.

α = β	20%	10%	5%
u	0.8416	1.2816	1.6449

Appendix 1

GUIDANCE ON THE DESIGN OF COMPLIANCE TEST PLANS FOR FAILURE RATIO

1. PURPOSE

This document is intended to be used for testing the compliance of an equipment to its specification of failed state detection probability. It can be used more generally in "either or" situations, e.g. for compliance evaluation of a failure ratio. The specivied failure ratio is the probability that an item cannot perform a required function or that an event will be unsuccessful under stated conditions. An observed failure ratio may be defined as the ratio of the number of failed items or unsuccessful events at the completion of testing to the total number of test items or events.

2. APPLICATION AREA

The method is applicable to cases where the following quantities are given:
— acceptable failure ratio;
— producer's nominal risk: consumer's nominal risk;
— total number of test items or events;
— possibly, the maximum value of the discrimination factor.

The method gives the following output quantities:
— discrimination factor (actual value);
— critical value (maximally allowed number of failed items or unsuccessful events).

3. RELATED DOCUMENTS

IEC: "Equipment reliability testing, part 5: compliance test plans for success ratio" (Publication 605-5, 1982).

4. SYMBOLS

P0: acceptable success ratio
q0: acceptable failure ratio: $1-P0$
P1: unacceptable ratio
q1: unacceptable failure ratio: $1-P1$
$D=q1/q0$ discrimination factor
α: producer's risk
β: consumer's risk
n: total number of test items or events
r: observed number of failed items or unsuccessful events
C: critical value. Maximally allowed number of failed items or unsuccessful events

Note. The critical value C is related to the quantity rRE used in IEC 605-5 Publication by: $C=rRE-1$.

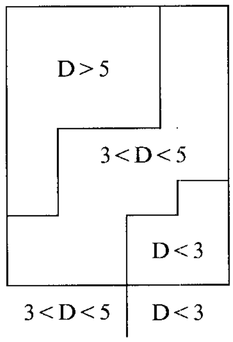
5. CALCULATION PROCEDURE

On the basis of the input quantities:

$$p0 \text{ (or } q0=1-p0), \; n \quad \alpha=\beta,$$

the derived parameters D and C are determined by means of graphs 1, 2, 3 (D values) and tables 1, 2, 3 (C values).

The tables also show roughly the discrimination factor according to:



Note.
If D > 5, then n must be increased.
If D > 3, it is recommended to increase n.
If D is larger than the (possibly) specified maximum value, then n should be increased.

6. DECISION CRITERIA

The calculated value C is compared with r, the observed number of failed items or unsuccessful events. If

— $r \leqslant C$, then the specified requirements are regarded as having been complied with
— $r > C$, then the specified requirements are regarded as having not been complied with

7. MATHEMATICAL BACKGROUND

7.1 The binomial distribution

If the probability of an event is q (approximately constant), then the probability that the event will occur exactly r times in n observations is:

$$P_{(r)} = \binom{r}{n} q^r (1-q)^{n-r}, \quad r = 0, 1, \ldots n \tag{1}$$

where

$$\binom{r}{n} = \frac{n!}{(n-r)!r!}$$

The probability $1 - P(r)$ of finding r or less events in n observations is:

$$1 - \alpha = P(r) = \sum_{i=0}^{r} \binom{i}{n} q^i (1-q)^{n-i} \tag{2}$$

For given n, q0 and α nom the C-value is calculated as the lowest integer satisfying

$$P(C) = \sum_{i=0}^{c} \binom{i}{n} q0^i (1-q0)^{n-i} \geqslant 1 - \alpha \text{ nom} \tag{3}$$

The tables 1, 2 and 3 shown are calculated according to (3) for all n.

7.2. Approximation formulas

A very convenient and rather good approximation for the described test plans is the arcsin transformation (given by R.A. Fisher) for confidence limits for the binomial distribution (ref. 2) with slight modifications:

For given q0, α and n, the following formula (4) can be applied to find the C value with extremely good approximation for the ranges:

$$0.001 \leqslant q0 \leqslant 0.20$$
$$2.5\% \leqslant \alpha \leqslant 30\%$$
$$n \geqslant 25$$

$$C \approx n \sin^2 \left[\arcsin (\sqrt{q0}) + \frac{u}{2\sqrt{n}} \right] - 0.5 \tag{4}$$

The calculated C value shall be rounded to the nearest integer.
$u = u_{1-\alpha}$ is the $1-\alpha$ fractile in the normal distribution.

The value of D for $\alpha=\beta$ can be calculated as:

$$D=\frac{\sin^2\left[\arcsin\left(\sqrt{q0}+\frac{u}{\sqrt{n}}\right)\right]}{q0} \tag{5}$$

The graphs 1, 2 and 3 shown are calculated according to (5).

7.3. **Accuracy**

In order to check the accuracy of the result obtained by the approximation formulas (4) and (5) the exact formula (2) may be used, as shown in the following example.

Example:

Given: q0 = 0.10, α nom = β nom = 10%, n = 25

Requested:

C, D, true α and β

Formula (4) gives: C = 4.23, rounded to 4

Formula (5) gives: D = 2.99

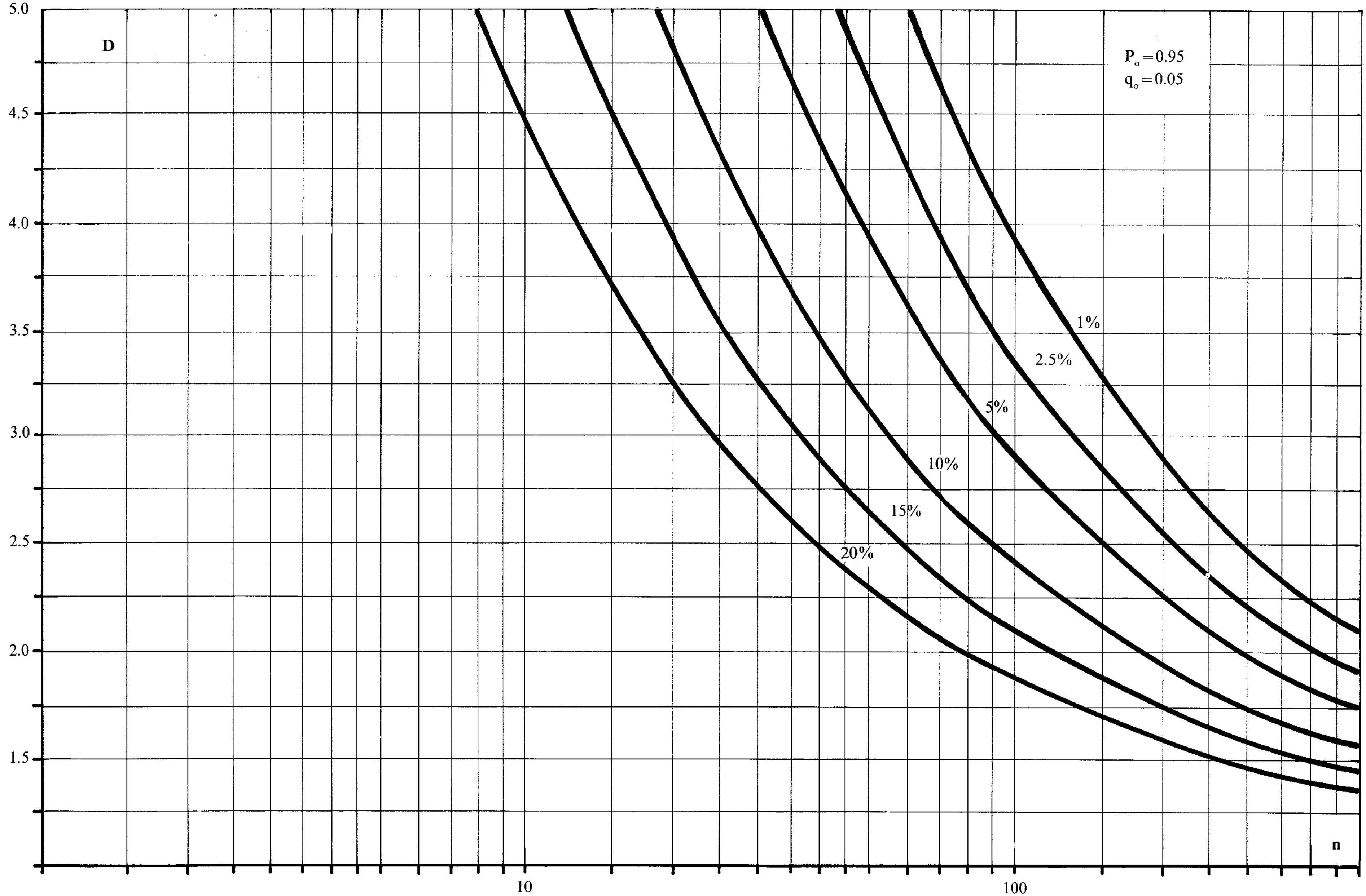
Formula (2) gives for q0 = 0.10: exact α = 9.8%

q1 = 0.30: exact β = 9.1%

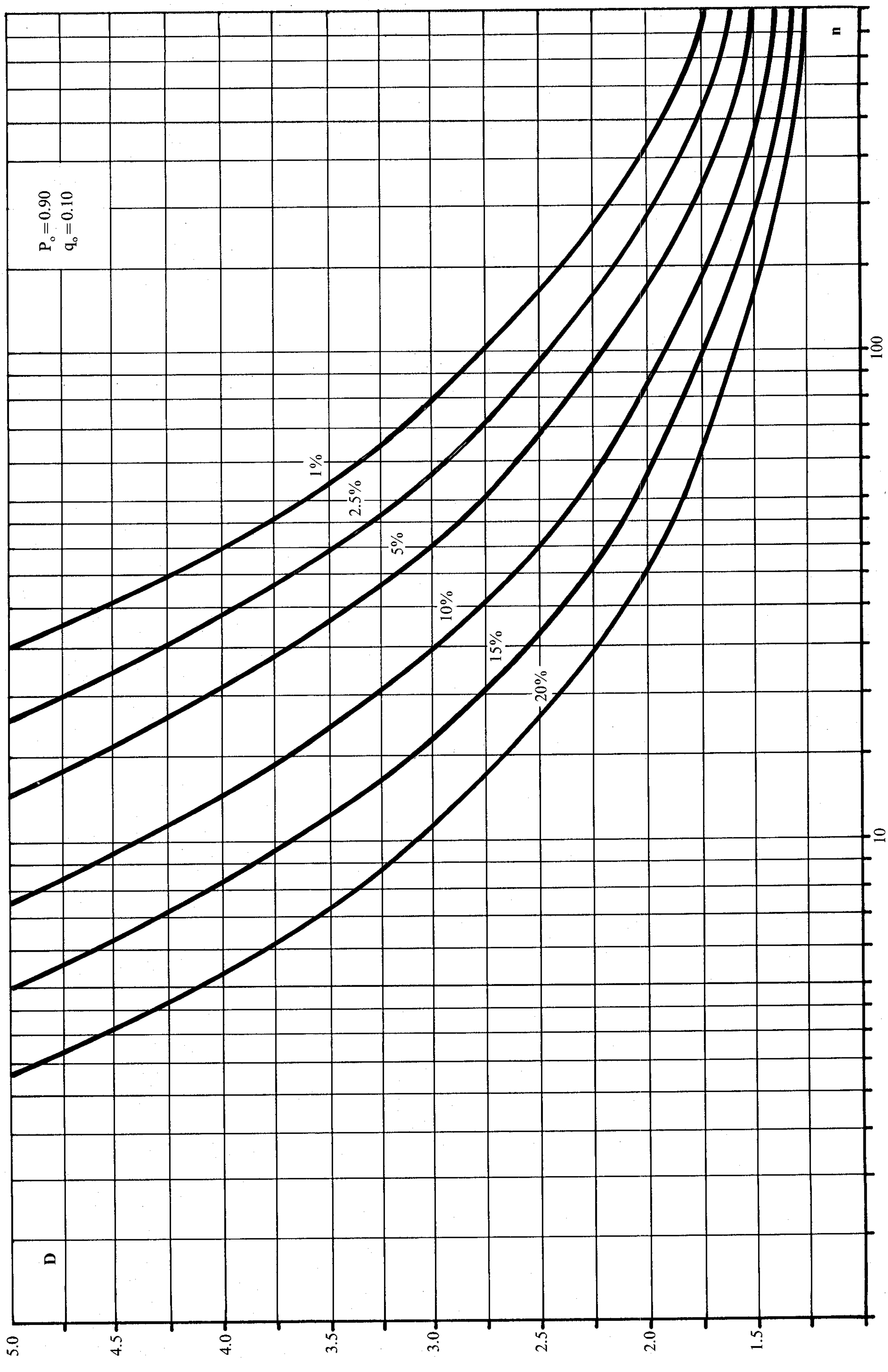
For p0 = 0.90, $\alpha=\beta$ = 10% and D = 3, IEC 605-5 Publication gives:

n = 25

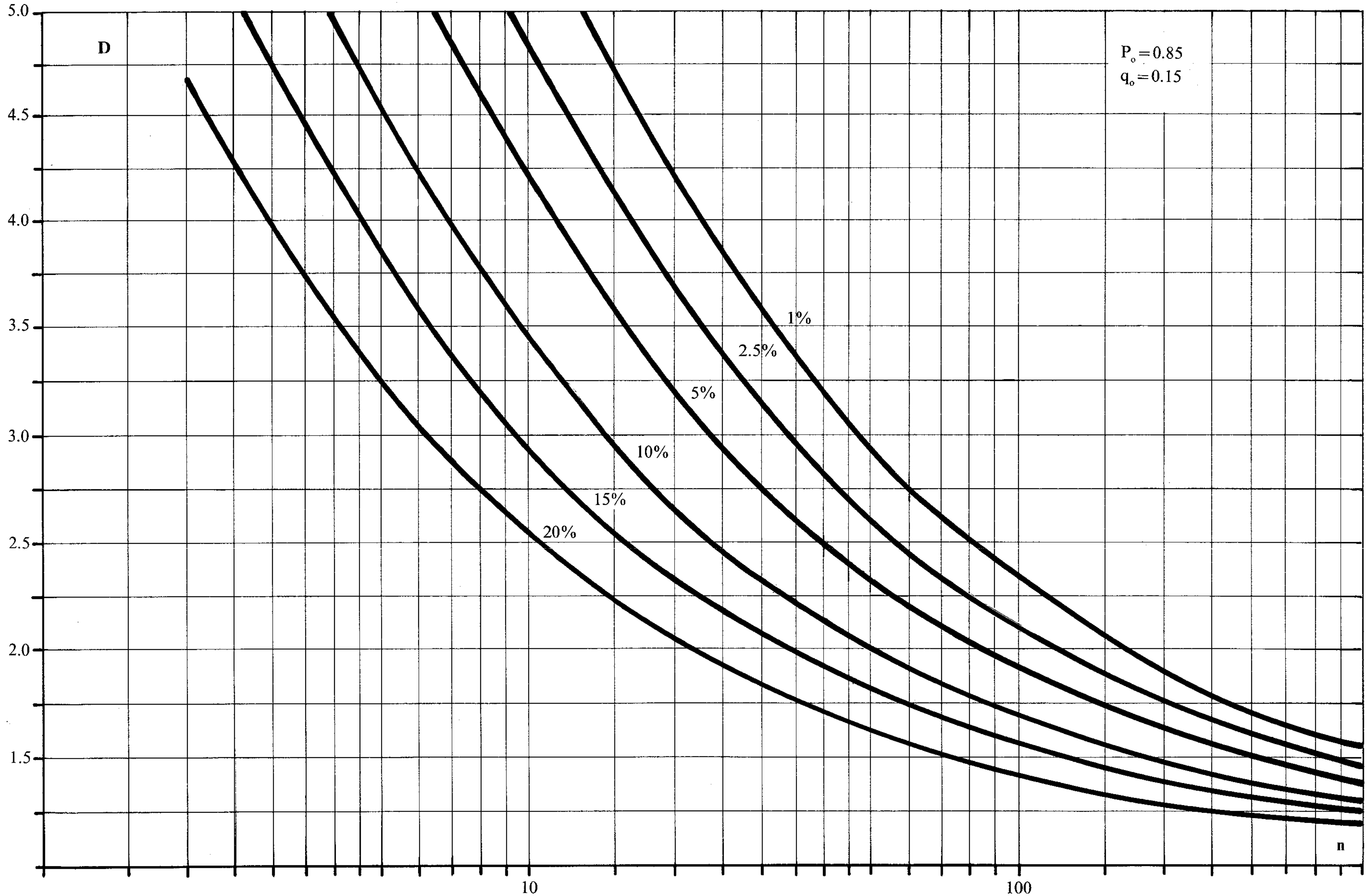
rRE = 5, that is C = 4.



GRAPH 1 (T/N 45-01). Discrimination factor $D = q1/q0$ versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom $= \beta$ nom (1%, 2.5%, 5%, 10%, 15%, 20%).



GRAPH 2 (T/N 45-01). Discrimination factor D = q1/q0 versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).



GRAPH 3 (T/N 45-01). Discrimination factor D = q1/q0 versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).

TABLE 1 (T/N 45-01). Critical value C versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).

$P_o = 0.95$ $q_o = 0.05$

n	C: α (%) 1.0	2.5	5	10	15	20
1	1	1	0	0	0	0
2	1	1	1	0	0	0
3	1	1	1	1	0	0
4	2	1	1	1	1	0
5	2	1	1	1	1	1
6	2	2	1	1	1	1
7	2	2	1	1	1	1
8	2	2	2	1	1	1
9	2	2	2	1	1	1
10	3	2	2	1	1	1
11	3	2	2	2	1	1
12	3	2	2	2	1	1
13	3	2	2	2	1	1
14	3	3	2	2	2	1
15	3	3	2	2	2	1
16	3	3	2	2	2	1
17	3	3	3	2	2	2
18	4	3	3	2	2	2
19	4	3	3	2	2	2
20	4	3	3	2	2	2
21	4	3	3	2	2	2
22	4	3	3	2	2	2
23	4	4	3	3	2	2
24	4	4	3	3	2	2
25	4	4	3	3	2	2
26	4	4	3	3	2	2
27	5	4	3	3	3	2
28	5	4	3	3	3	2
29	5	4	4	3	3	2
30	5	4	4	3	3	2
31	5	4	4	3	3	3
32	5	4	4	3	3	3
33	5	4	4	3	3	3
34	5	5	4	3	3	3
35	5	5	4	3	3	3
36	5	5	4	4	3	3
37	5	5	4	4	3	3

n	C: α (%) 1.0	2.5	5	10	15	20
51	7	6	5	5	4	4
52	7	6	5	5	4	4
53	7	6	5	5	4	4
54	7	6	6	5	4	4
55	7	6	6	5	4	4
56	7	6	6	5	4	4
57	7	6	6	5	5	4
58	7	7	6	5	5	4
59	7	7	6	5	5	4
60	7	7	6	5	5	4
61	8	7	6	5	5	4
62	8	7	6	5	5	4
63	8	7	6	5	5	5
64	8	7	6	6	5	5
65	8	7	6	6	5	5
66	8	7	6	6	5	5
67	8	7	6	6	5	5
68	8	7	7	6	5	5
69	8	7	7	6	5	5
70	8	7	7	6	5	5
71	8	8	7	6	5	5
72	8	8	7	6	6	5
73	9	8	7	6	6	5
74	9	8	7	6	6	5
75	9	8	7	6	6	5
76	9	8	7	6	6	5
77	9	8	7	6	6	5
78	9	8	7	6	6	5
79	9	8	7	7	6	6
80	9	8	7	7	6	6
81	9	8	7	7	6	6
82	9	8	8	7	6	6
83	9	8	8	7	6	6
84	9	8	8	7	6	6
85	9	9	8	7	6	6
86	10	9	8	7	6	6
87	10	9	8	7	6	6

n	C: α (%) 1.0	2.5	5	10	15	20
101	11	10	9	8	7	7
102	11	10	9	8	7	7
103	11	10	9	8	7	7
104	11	10	9	8	7	7
105	11	10	9	8	8	7
106	11	10	9	8	8	7
107	11	10	9	8	8	7
108	11	10	9	8	8	7
109	11	10	9	8	8	7
110	11	10	9	9	8	7
111	11	10	10	9	8	7
112	12	10	10	9	8	7
113	12	11	10	9	8	8
114	12	11	10	9	8	8
115	12	11	10	9	8	8
116	12	11	10	9	8	8
117	12	11	10	9	8	8
118	12	11	10	9	8	8
119	12	11	10	9	8	8
120	12	11	10	9	8	8
121	12	11	10	9	9	8
122	12	11	10	9	9	8
123	12	11	10	9	9	8
124	12	11	10	9	9	8
125	13	11	10	9	9	8
126	13	11	11	10	9	8
127	13	12	11	10	9	8
128	13	12	11	10	9	8
129	13	12	11	10	9	8
130	13	12	11	10	9	9
131	13	12	11	10	9	9
132	13	12	11	10	9	9
133	13	12	11	10	9	9
134	13	12	11	10	9	9
135	13	12	11	10	9	9
136	13	12	11	10	9	9
137	13	12	11	10	9	9

TABLE 1 (T/N 45-01) (*Continued*). Critical value C versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).

$P_o = 0.95$ $q_o = 0.05$

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
151	14	13	12	11	10	10
152	14	13	12	11	10	10
153	15	13	12	11	10	10
154	15	13	12	11	11	10
155	15	13	12	11	11	10
156	15	14	13	11	11	10
157	15	14	13	11	11	10
158	15	14	13	11	11	10
159	15	14	13	12	11	10
160	15	14	13	12	11	10
161	15	14	13	12	11	10
162	15	14	13	12	11	10
163	15	14	13	12	11	10
164	15	14	13	12	11	10
165	15	14	13	12	11	11
166	15	14	13	12	11	11
167	15	14	13	12	11	11
168	16	14	13	12	11	11
169	16	14	13	12	11	11
170	16	14	13	12	11	11
171	16	15	13	12	12	11
172	16	15	14	12	12	11
173	16	15	14	12	12	11
174	16	15	14	12	12	11
175	16	15	14	13	12	11
176	16	15	14	13	12	11
177	16	15	14	13	12	11
178	16	15	14	13	12	11
179	16	15	14	13	12	11
180	16	15	14	13	12	11
181	16	15	14	13	12	11
182	17	15	14	13	12	12
183	17	15	14	13	12	12
184	17	15	14	13	12	12
185	17	15	14	13	12	12
186	17	16	14	13	12	12
187	17	16	14	13	12	12
188	17	16	15	13	12	12
189	17	16	15	13	13	12
190	17	16	15	13	13	12
191	17	16	15	13	13	12
192	17	16	15	14	13	12
193	17	16	15	14	13	12
194	17	16	15	14	13	12
195	17	16	15	14	13	12
196	17	16	15	14	13	12
197	18	16	15	14	13	12
198	18	16	15	14	13	12
199	18	16	15	14	13	12
200	18	16	15	14	13	13

D<3

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
201	18	16	15	14	13	13
202	18	17	15	14	13	13
203	18	17	15	14	13	13
204	18	17	16	14	13	13
205	18	17	16	14	13	13
206	18	17	16	14	14	13
207	18	17	16	14	14	13
208	18	17	16	15	14	13
209	18	17	16	15	14	13
210	18	17	16	15	14	13
211	19	17	16	15	14	13
212	19	17	16	15	14	13
213	19	17	16	15	14	13
214	19	17	16	15	14	13
215	19	17	16	15	14	13
216	19	17	16	15	14	13
217	19	18	16	15	14	13
218	19	18	16	15	14	14
219	19	18	16	15	14	14
220	19	18	17	15	14	14
221	19	18	17	15	14	14
222	19	18	17	15	14	14
223	19	18	17	15	15	14
224	19	18	17	15	15	14
225	19	18	17	16	15	14
226	20	18	17	16	15	14
227	20	18	17	16	15	14
228	20	18	17	16	15	14
229	20	18	17	16	15	14
230	20	18	17	16	15	14
231	20	18	17	16	15	14
232	20	18	17	16	15	14
233	20	19	17	16	15	14
234	20	19	17	16	15	14
235	20	19	17	16	15	15
236	20	19	18	16	15	15
237	20	19	18	16	15	15
238	20	19	18	16	15	15
239	20	19	18	16	15	15
240	20	19	18	16	15	15
241	21	19	18	16	16	15
242	21	19	18	17	16	15
243	21	19	18	17	16	15
244	21	19	18	17	16	15
245	21	19	18	17	16	15
246	21	19	18	17	16	15
247	21	19	18	17	16	15
248	21	20	18	17	16	15
249	21	20	18	17	16	15
250	21	20	18	17	16	15

D<3

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
251	21	20	18	17	16	15
252	21	20	19	17	16	15
253	21	20	19	17	16	16
254	21	20	19	17	16	16
255	21	20	19	17	16	16
256	22	20	19	17	16	16
257	22	20	19	17	16	16
258	22	20	19	17	17	16
259	22	20	19	18	17	16
260	22	20	19	18	17	16
261	22	20	19	18	17	16
262	22	20	19	18	17	16
263	22	20	19	18	17	16
264	22	21	19	18	17	16
265	22	21	19	18	17	16
266	22	21	19	18	17	16
267	22	21	19	18	17	16
268	22	21	19	18	17	16
269	22	21	20	18	17	16
270	22	21	20	18	17	16
271	23	21	20	18	17	17
272	23	21	20	18	17	17
273	23	21	20	18	17	17
274	23	21	20	18	17	17
275	23	21	20	18	17	17
276	23	21	20	19	18	17
277	23	21	20	19	18	17
278	23	21	20	19	18	17
279	23	21	20	19	18	17
280	23	22	20	19	18	17
281	23	22	20	19	18	17
282	23	22	20	19	18	17
283	23	22	20	19	18	17
284	23	22	20	19	18	17
285	23	22	21	19	18	17
286	23	22	21	19	18	17
287	24	22	21	19	18	17
288	24	22	21	19	18	17
289	24	22	21	19	18	18
290	24	22	21	19	18	18
291	24	22	21	19	18	18
292	24	22	21	19	18	18
293	24	22	21	20	19	18
294	24	22	21	20	19	18
295	24	22	21	20	19	18
296	24	23	21	20	19	18
297	24	23	21	20	19	18
298	24	23	21	20	19	18
299	24	23	21	20	19	18
300	24	23	21	20	19	18

D<3

TABLE 2 (T/N 45-01). Critical value C versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).

$P_o = 0.90$ $q_o = 0.10$

n	C α (%) 1.0	2.5	5	10	15	20
1	1	1	1	0	0	0
2	1	1	1	1	1	0
3	2	2	1	1	1	1
4	2	2	2	1	1	1
5	2	2	2	1	1	1
6	3	2	2	2	1	1
7	3	3	2	2	1	1
8	3	3	2	2	2	1
9	3	3	3	2	2	2
10	4	3	3	2	2	2
11	4	3	3	2	2	2
12	4	4	3	3	2	2
13	4	4	3	3	2	2
14	4	4	3	3	3	2
15	5	4	4	3	3	2
16	5	4	4	3	3	3
17	5	4	4	3	3	3
18	5	5	4	3	3	3
19	5	5	4	4	3	3
20	6	5	4	4	3	3
21	6	5	5	4	4	3
22	6	5	5	4	4	3
23	6	5	5	4	4	3
24	6	6	5	4	4	4
25	6	6	5	4	4	4
26	7	6	5	5	4	4
27	7	6	5	5	4	4
28	7	6	6	5	4	4
29	7	6	6	5	5	4
30	7	7	6	5	5	4
31	7	7	6	5	5	4
32	8	7	6	5	5	5
33	8	7	6	6	5	5
34	8	7	6	6	5	5
35	8	7	7	6	5	5
36	8	7	7	6	5	5
37	8	8	7	6	6	5
38	9	8	7	6	6	5
39	9	8	7	6	6	5
40	9	8	7	6	6	6
41	9	8	7	7	6	6
42	9	8	8	7	6	6
43	9	8	8	7	6	6
44	10	9	8	7	6	6
45	10	9	8	7	7	6
46	10	9	8	7	7	6
47	10	9	8	7	7	6
48	10	9	8	8	7	7
49	10	9	9	8	7	7
50	10	9	9	8	7	7

$3 < D < 5$ | $D < 3$

n	C α (%) 1.0	2.5	5	10	15	20
51	11	10	9	8	7	7
52	11	10	9	8	7	7
53	11	10	9	8	8	7
54	11	10	9	8	8	7
55	11	10	9	8	8	7
56	11	10	9	9	8	7
57	11	10	10	9	8	8
58	12	11	10	9	8	8
59	12	11	10	9	8	8
60	12	11	10	9	8	8
61	12	11	10	9	9	8
62	12	11	10	9	9	8
63	12	11	10	9	9	8
64	12	11	11	10	9	8
65	13	12	11	10	9	8
66	13	12	11	10	9	9
67	13	12	11	10	9	9
68	13	12	11	10	9	9
69	13	12	11	10	9	9
70	13	12	11	10	10	9
71	13	12	11	10	10	9
72	14	13	12	11	10	9
73	14	13	12	11	10	9
74	14	13	12	11	10	10
75	14	13	12	11	10	10
76	14	13	12	11	10	10
77	14	13	12	11	10	10
78	14	13	12	11	11	10
79	15	13	12	11	11	10
80	15	14	13	12	11	10
81	15	14	13	12	11	10
82	15	14	13	12	11	10
83	15	14	13	12	11	11
84	15	14	13	12	11	11
85	15	14	13	12	11	11
86	16	14	13	12	11	11
87	16	15	14	12	12	11
88	16	15	14	12	12	11
89	16	15	14	13	12	11
90	16	15	14	13	12	11
91	16	15	14	13	12	11
92	16	15	14	13	12	12
93	17	15	14	13	12	12
94	17	15	14	13	12	12
95	17	16	15	13	13	12
96	17	16	15	13	13	12
97	17	16	15	14	13	12
98	17	16	15	14	13	12
99	17	16	15	14	13	12
100	18	16	15	14	13	12

$D < 3$

n	C α (%) 1.0	2.5	5	10	15	20
101	18	16	15	14	13	13
102	18	16	15	14	13	13
103	18	17	16	14	13	13
104	18	17	16	14	14	13
105	18	17	16	15	14	13
106	18	17	16	15	14	13
107	18	17	16	15	14	13
108	19	17	16	15	14	13
109	19	17	16	15	14	13
110	19	18	16	15	14	14
111	19	18	17	15	14	14
112	19	18	17	15	14	14
113	19	18	17	15	15	14
114	19	18	17	16	15	14
115	20	18	17	16	15	14
116	20	18	17	16	15	14
117	20	18	17	16	15	14
118	20	19	17	16	15	14
119	20	19	17	16	15	15
120	20	19	18	16	15	15
121	20	19	18	16	16	15
122	20	19	18	17	16	15
123	21	19	18	17	16	15
124	21	19	18	17	16	15
125	21	19	18	17	16	15
126	21	20	18	17	16	15
127	21	20	18	17	16	16
128	21	20	19	17	16	16
129	21	20	19	17	16	16
130	21	20	19	17	17	16
131	22	20	19	18	17	16
132	22	20	19	18	17	16
133	22	20	19	18	17	16
134	22	21	19	18	17	16
135	22	21	19	18	17	16
136	22	21	20	18	17	16
137	22	21	20	18	17	17
138	23	21	20	18	17	17
139	23	21	20	19	18	17
140	23	21	20	19	18	17
141	23	21	20	19	18	17
142	23	22	20	19	18	17
143	23	22	20	19	18	17
144	23	22	21	19	18	17
145	23	22	21	19	18	17
146	24	22	21	19	18	18
147	24	22	21	19	18	18
148	24	22	21	20	19	18
149	24	22	21	20	19	18
150	24	23	21	20	19	18

$D < 3$

(To be continued)

TABLE 2 (T/N 45-01) (*Continued*). Critical value C versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).

$P_o = 0.90$ $q_o = 0.10$

n	C α (%) 1.0	2.5	5	10	15	20
151	24	23	21	20	19	18
152	24	23	21	20	19	18
153	24	23	22	20	19	18
154	25	23	22	20	19	18
155	25	23	22	20	19	19
156	25	23	22	20	19	19
157	25	23	22	21	20	19
158	25	24	22	21	20	19
159	25	24	22	21	20	19
160	25	24	22	21	20	19
161	25	24	23	21	20	19
162	26	24	23	21	20	19
163	26	24	23	21	20	19
164	26	24	23	21	20	20
165	26	24	23	22	20	20
166	26	25	23	22	21	20
167	26	25	23	22	21	20
168	26	25	23	22	21	20
169	27	25	24	22	21	20
170	27	25	24	22	21	20
171	27	25	24	22	21	20
172	27	25	24	22	21	20
173	27	25	24	22	21	21
174	27	26	24	23	22	21
175	27	26	24	23	22	21
176	27	26	24	23	22	21
177	28	26	24	23	22	21
178	28	26	25	23	22	21
179	28	26	25	23	22	21
180	28	26	25	23	22	21
181	28	26	25	23	22	21
182	28	26	25	23	22	22
183	28	27	25	24	23	22
184	28	27	25	24	23	22
185	29	27	25	24	23	22
186	29	27	26	24	23	22
187	29	27	26	24	23	22
188	29	27	26	24	23	22
189	29	27	26	24	23	22
190	29	27	26	24	23	22
191	29	28	26	24	23	23
192	29	28	26	25	24	23
193	30	28	26	25	24	23
194	30	28	26	25	24	23
195	30	28	27	25	24	23
196	30	28	27	25	24	23
197	30	28	27	25	24	23
198	30	28	27	25	24	23
199	30	29	27	25	24	23
200	30	29	27	26	24	24

D < 3

n	C α (%) 1.0	2.5	5	10	15	20
201	31	29	27	26	25	24
202	31	29	27	26	25	24
203	31	29	28	26	25	24
204	31	29	28	26	25	24
205	31	29	28	26	25	24
206	31	29	28	26	25	24
207	31	30	28	26	25	24
208	31	30	28	26	25	24
209	32	30	28	27	25	25
210	32	30	28	27	26	25
211	32	30	28	27	26	25
212	32	30	29	27	26	25
213	32	30	29	27	26	25
214	32	30	29	27	26	25
215	32	30	29	27	26	25
216	32	31	29	27	26	25
217	33	31	29	27	26	25
218	33	31	29	28	26	25
219	33	31	29	28	27	26
220	33	31	30	28	27	26
221	33	31	30	28	27	26
222	33	31	30	28	27	26
223	33	31	30	28	27	26
224	33	32	30	28	27	26
225	34	32	30	28	27	26
226	34	32	30	28	27	26
227	34	32	30	29	27	26
228	34	32	30	29	27	27
229	34	32	31	29	28	27
230	34	32	31	29	28	27
231	34	32	31	29	28	27
232	34	33	31	29	28	27
233	34	33	31	29	28	27
234	35	33	31	29	28	27
235	35	33	31	29	28	27
236	35	33	31	30	28	27
237	35	33	32	30	28	28
238	35	33	32	30	29	28
239	35	33	32	30	29	28
240	35	33	32	30	29	28
241	35	34	32	30	29	28
242	36	34	32	30	29	28
243	36	34	32	30	29	28
244	36	34	32	30	29	28
245	36	34	32	31	29	28
246	36	34	33	31	29	29
247	36	34	33	31	30	29
248	36	34	33	31	30	29
249	36	35	33	31	30	29
250	37	35	33	31	30	29

D < 3

n	C α (%) 1.0	2.5	5	10	15	20
251	37	35	33	31	30	29
252	37	35	33	31	30	29
253	37	35	33	31	30	29
254	37	35	33	32	30	29
255	37	35	34	32	30	29
256	37	35	34	32	31	30
257	37	35	34	32	31	30
258	38	36	34	32	31	30
259	38	36	34	32	31	30
260	38	36	34	32	31	30
261	38	36	34	32	31	30
262	38	36	34	32	31	30
263	38	36	35	33	31	30
264	38	36	35	33	31	30
265	38	36	35	33	32	31
266	39	37	35	33	32	31
267	39	37	35	33	32	31
268	39	37	35	33	32	31
269	39	37	35	33	32	31
270	39	37	35	33	32	31
271	39	37	35	34	32	31
272	39	37	36	34	32	31
273	39	37	36	34	32	31
274	39	37	36	34	33	32
275	40	38	36	34	33	32
276	40	38	36	34	33	32
277	40	38	36	34	33	32
278	40	38	36	34	33	32
279	40	38	36	34	33	32
280	40	38	36	35	33	32
281	40	38	37	35	33	32
282	40	38	37	35	33	32
283	41	39	37	35	34	33
284	41	39	37	35	34	33
285	41	39	37	35	34	33
286	41	39	37	35	34	33
287	41	39	37	35	34	33
288	41	39	37	35	34	33
289	41	39	37	36	34	33
290	41	39	38	36	34	33
291	42	39	38	36	34	33
292	42	40	38	36	35	33
293	42	40	38	36	35	34
294	42	40	38	36	35	34
295	42	40	38	36	35	34
296	42	40	38	36	35	34
297	42	40	38	36	35	34
298	42	40	39	37	35	34
299	43	40	39	37	35	34
300	43	41	39	37	35	34

D < 3

TABLE 3 (T/N 45-01). Critical value C versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).

$P_o = 0.85$ $q_o = 0.15$

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
1	1	1	1	1	0	0
2	2	1	1	1	1	1
3	2	2	2	1	1	1
4	3	2	2	2	1	1
5	3	3	2	2	2	1
6	3	3	2	2	2	2
7	4	3	3	2	2	2
8	4	3	3	3	2	2
9	4	4	3	3	2	2
10	4	4	3	3	3	2
11	5	4	4	3	3	3
12	5	4	4	3	3	3
13	5	5	4	4	3	3
14	6	5	4	4	3	3
15	6	5	5	4	4	3
16	6	5	5	4	4	4
17	6	6	5	4	4	4
18	7	6	5	5	4	4
19	7	6	6	5	4	4
20	7	6	6	5	5	4
21	7	7	6	5	5	4
22	8	7	6	5	5	5
23	8	7	6	6	5	5
24	8	7	7	6	5	5
25	8	8	7	6	6	5
26	9	8	7	6	6	5
27	9	8	7	6	6	6
28	9	8	7	7	6	6
29	9	8	8	7	6	6
30	9	9	8	7	7	6
31	10	9	8	7	7	6
32	10	9	8	7	7	6
33	10	9	8	8	7	7
34	10	9	9	8	7	7
35	11	10	9	8	7	7
36	11	10	9	8	8	7
37	11	10	9	8	8	7
38	11	10	9	9	8	8
39	11	10	10	9	8	8
40	12	11	10	9	8	8
41	12	11	10	9	9	8
42	12	11	10	9	9	8
43	12	11	10	10	9	8
44	13	12	11	10	9	9
45	13	12	11	10	9	9
46	13	12	11	10	9	9
47	13	12	11	10	10	9
48	13	12	11	10	10	9
49	14	13	12	11	10	9
50	14	13	12	11	10	10

D<3

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
51	14	13	12	11	10	10
52	14	13	12	11	10	10
53	14	13	12	11	11	10
54	15	14	13	12	11	10
55	15	14	13	12	11	10
56	15	14	13	12	11	11
57	15	14	13	12	11	11
58	15	14	13	12	12	11
59	16	15	14	12	12	11
60	16	15	14	13	12	11
61	16	15	14	13	12	11
62	16	15	14	13	12	12
63	16	15	14	13	12	12
64	17	15	14	13	13	12
65	17	16	15	14	13	12
66	17	16	15	14	13	12
67	17	16	15	14	13	12
68	17	16	15	14	13	13
69	18	16	15	14	13	13
70	18	17	16	14	14	13
71	18	17	16	15	14	13
72	18	17	16	15	14	13
73	18	17	16	15	14	13
74	19	17	16	15	14	14
75	19	18	17	15	14	14
76	19	18	17	15	15	14
77	19	18	17	16	15	14
78	19	18	17	16	15	14
79	20	18	17	16	15	14
80	20	19	17	16	15	15
81	20	19	18	16	15	15
82	20	19	18	17	16	15
83	20	19	18	17	16	15
84	21	19	18	17	16	15
85	21	19	18	17	16	15
86	21	20	19	17	16	16
87	21	20	19	17	17	16
88	21	20	19	18	17	16
89	22	20	19	18	17	16
90	22	20	19	18	17	16
91	22	21	19	18	17	16
92	22	21	20	18	17	17
93	22	21	20	18	18	17
94	23	21	20	19	18	17
95	23	21	20	19	18	17
96	23	22	20	19	18	17
97	23	22	21	19	18	17
98	23	22	21	19	18	18
99	24	22	21	19	19	18
100	24	22	21	20	19	18

D<3

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
101	24	22	21	20	19	18
102	24	23	21	20	19	18
103	24	23	22	20	19	18
104	25	23	22	20	19	19
105	25	23	22	21	20	19
106	25	23	22	21	20	19
107	25	24	22	21	20	19
108	25	24	22	21	20	19
109	25	24	23	21	20	19
110	26	24	23	21	20	20
111	26	24	23	22	21	20
112	26	25	23	22	21	20
113	26	25	23	22	21	20
114	26	25	24	22	21	20
115	27	25	24	22	21	20
116	27	25	24	22	21	21
117	27	25	24	23	22	21
118	27	26	24	23	22	21
119	27	26	24	23	22	21
120	28	26	25	23	22	21
121	28	26	25	23	22	21
122	28	26	25	23	22	22
123	28	27	25	24	23	22
124	28	27	25	24	23	22
125	29	27	25	24	23	22
126	29	27	26	24	23	22
127	29	27	26	24	23	22
128	29	27	26	24	23	23
129	29	28	26	25	24	23
130	29	28	26	25	24	23
131	30	28	27	25	24	23
132	30	28	27	25	24	23
133	30	28	27	25	24	23
134	30	29	27	25	24	24
135	30	29	27	26	25	24
136	31	29	27	26	25	24
137	31	29	28	26	25	24
138	31	29	28	26	25	24
139	31	29	28	26	25	24
140	31	30	28	26	25	25
141	31	30	28	27	26	25
142	32	30	28	27	26	25
143	32	30	29	27	26	25
144	32	30	29	27	26	25
145	32	30	29	27	26	25
146	32	31	29	27	26	25
147	33	31	29	28	27	26
148	33	31	30	28	27	26
149	33	31	30	28	27	26
150	33	31	30	28	27	26

D<3

(To be continued)

TABLE 3 (T/N 45-01) (*Continued*). Critical value C versus observed number of events n, for fixed p0 (or q0) and for different risk levels α nom = β nom (1%, 2.5%, 5%, 10%, 15%, 20%).

$P_o = 0.85$ $q_o = 0.15$

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
151	33	32	30	28	27	26
152	34	32	30	29	27	26
153	34	32	30	29	28	27
154	34	32	31	29	28	27
155	34	32	31	29	28	27
156	34	32	31	29	28	27
157	34	33	31	29	28	27
158	35	33	31	30	28	27
159	35	33	31	30	29	28
160	35	33	32	30	29	28
161	35	33	32	30	29	28
162	35	34	32	30	29	28
163	36	34	32	30	29	28
164	36	34	32	31	29	28
165	36	34	32	31	30	29
166	36	34	33	31	30	29
167	36	34	33	31	30	29
168	36	35	33	31	30	29
169	37	35	33	31	30	29
170	37	35	33	32	30	29
171	37	35	34	32	30	30
172	37	35	34	32	31	30
173	37	35	34	32	31	30
174	38	36	34	32	31	30
175	38	36	34	32	31	30
176	38	36	34	33	31	30
177	38	36	35	33	31	31
178	38	36	35	33	32	31
179	38	37	35	33	32	31
180	39	37	35	33	32	31
181	39	37	35	33	32	31
182	39	37	35	34	32	31
183	39	37	36	34	32	31
184	39	37	36	34	33	32
185	40	38	36	34	33	32
186	40	38	36	34	33	32
187	40	38	36	34	33	32
188	40	38	36	35	33	32
189	40	38	37	35	33	32
190	40	38	37	35	34	33
191	41	39	37	35	34	33
192	41	39	37	35	34	33
193	41	39	37	35	34	33
194	41	39	37	36	34	33
195	41	39	38	36	34	33
196	42	40	38	36	35	34
197	42	40	38	36	35	34
198	42	40	38	36	35	34
199	42	40	38	36	35	34
200	42	40	38	37	35	34

D < 3

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
201	42	40	39	37	35	34
202	43	41	39	37	36	35
203	43	41	39	37	36	35
204	43	41	39	37	36	35
205	43	41	39	37	36	35
206	43	41	40	38	36	35
207	43	41	40	38	36	35
208	44	42	40	38	37	35
209	44	42	40	38	37	36
210	44	42	40	38	37	36
211	44	42	40	38	37	36
212	44	42	41	39	37	36
213	45	42	41	39	37	36
214	45	43	41	39	38	36
215	45	43	41	39	38	37
216	45	43	41	39	38	37
217	45	43	41	39	38	37
218	45	43	42	40	38	37
219	46	44	42	40	38	37
220	46	44	42	40	38	37
221	46	44	42	40	39	38
222	46	44	42	40	39	38
223	46	44	42	40	39	38
224	47	44	43	41	39	38
225	47	45	43	41	39	38
226	47	45	43	41	39	38
227	47	45	43	41	40	39
228	47	45	43	41	40	39
229	47	45	43	41	40	39
230	48	45	44	42	40	39
231	48	46	44	42	40	39
232	48	46	44	42	40	39
233	48	46	44	42	41	40
234	48	46	44	42	41	40
235	48	46	44	42	41	40
236	49	46	45	42	41	40
237	49	47	45	43	41	40
238	49	47	45	43	41	40
239	49	47	45	43	42	40
240	49	47	45	43	42	41
241	50	47	45	43	42	41
242	50	47	46	43	42	41
243	50	48	46	44	42	41
244	50	48	46	44	42	41
245	50	48	46	44	43	41
246	50	48	46	44	43	42
247	51	48	46	44	43	42
248	51	49	47	44	43	42
249	51	49	47	45	43	42
250	51	49	47	45	43	42

D < 3

n	C					
	α (%)					
	1.0	2.5	5	10	15	20
251	51	49	47	45	44	42
252	51	49	47	45	44	43
253	52	49	47	45	44	43
254	52	50	48	45	44	43
255	52	50	48	46	44	43
256	52	50	48	46	44	43
257	52	50	48	46	44	43
258	53	50	48	46	45	43
259	53	50	48	46	45	44
260	53	51	49	46	45	44
261	53	51	49	47	45	44
262	53	51	49	47	45	44
263	53	51	49	47	45	44
264	54	51	49	47	46	44
265	54	51	49	47	46	45
266	54	52	50	47	46	45
267	54	52	50	48	46	45
268	54	52	50	48	46	45
269	54	52	50	48	46	45
270	55	52	50	48	47	45
271	55	52	51	48	47	46
272	55	53	51	48	47	46
273	55	53	51	49	47	46
274	55	53	51	49	47	46
275	56	53	51	49	47	46
276	56	53	51	49	48	46
277	56	54	52	49	48	47
278	56	54	52	49	48	47
279	56	54	52	50	48	47
280	56	54	52	50	48	47
281	57	54	52	50	48	47
282	57	54	52	50	49	47
283	57	55	53	50	49	47
284	57	55	53	50	49	48
285	57	55	53	51	49	48
286	57	55	53	51	49	48
287	58	55	53	51	49	48
288	58	55	53	51	49	48
289	58	56	54	51	50	48
290	58	56	54	51	50	49
291	58	56	54	52	50	49
292	58	56	54	52	50	49
293	59	56	54	52	50	49
294	59	56	54	52	50	49
295	59	57	55	52	51	49
296	59	57	55	52	51	50
297	59	57	55	53	51	50
298	60	57	55	53	51	50
299	60	57	55	53	51	50
300	60	57	55	53	51	50

D < 3