MIL-STD-781C
21 October 1977

SUPERSEDING
MIL-STD-781B

MILITARY STANDARD

RELIABILITY DESIGN QUALIFICATION AND PRODUCTION ACCEPTANCE TESTS: EXPONENTIAL DISTRIBUTION

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DEPARTMENT OF DEFENSE
Washington, D.C. 20360

Reliability Design Qualification and Production Acceptance Tests:
Exponential Distribution

MIL-STD-781C
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1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Electronic Systems Command, ATTN: 50431, Washington, D.C. 20360, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

1. MIL-STD-781C is a complete revision of MIL-STD-781B and makes extensive use of appendices. The appendices expand and clarify various sections of the standard and will aid both procuring activity and producer in the application of this standard.

2. The definitions of the mean-time-between-failures (MTBF) requirements have been changed to clarify the use of θ_0 and θ_1 which are test plan parameters. θ_1, the lower test MTBF, is an unacceptable MTBF based on minimum requirements. θ_0 is the upper test MTBF and the acceptable MTBF. The ratio of θ_0 to θ_1 is defined as the discrimination ratio. Specifying any two of these three parameters, given the desired decision risks, determines the test plan to be utilized. The new definitions enable the lower test MTBF to be held constant (which should be the case since that value is the threshold of the required MTBF) when choosing a test plan. Previously, under MIL-STD-781B, the minimum acceptable MTBF changed with the test plan making the concept of a minimum acceptable (or a lower limit) MTBF ineffective. For example, under MIL-STD-781B definitions θ_0 was the specified value of MTBF and if θ_0 = 400 hours and Test Plan III was the required qualification test plan, θ_1 would equal 200 hours; if Test Plan V was used, θ_1 would equal 133 hours; if Test Plan VI was used, θ_1 would only be 80 hours. Furthermore, the predicted MTBF was required to be no less than the minimum acceptable θ_1. However, to assure a high probability of reaching an accept decision under a particular test plan, the equipment's design-predicted MTBF should approach θ_0 in value.

3. The other major change in MIL-STD-781 is the use of combined environmental test conditions (temperature, vibration and moisture) based on the actual mission profile environments encountered during the equipment's useful life. Altitude may be included if the procuring activity determines that it is cost-effective. Furthermore, facilitation cost for combining altitude with the other environments would probably not be cost-effective.

4. This standard should not be invoked on a blanket basis but each requirement assessed in terms of the need. Appendices are set-up so that the procuring activity may reference them with specific parts of the standard and invoked in the equipment specification, for example; combined environments for turboprop aircraft and helicopter equipment (Section 50.5 of APP B).

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1. SCOPE

1.1 Scope. This standard covers the requirements for reliability qualification tests (preproduction) and reliability acceptance tests (production) for equipment that experiences a distribution of times-to-failure that is exponential. These requirements include: test conditions, procedures, and various fixed length and sequential test plans with respective accept/reject criteria.

1.2 Application. The application of this standard is intended to provide the procuring activity with decision information prior to award of a production contract, based on realistic test and evaluation of equipment performance and reliability, under specified environmental conditions. It is also intended that the standard provide guidelines for determining test conditions which shall apply to production reliability acceptance testing. These tests should be accomplished under one of the following locations and conditions, selected from the listed order of priority and authorized by the procuring activity.

a. Test in government or commercial laboratory independent of the developing/producing contractor
b. Have prime contractor test subcontractors' products under government surveillance
c. Allow contractor to conduct these tests in his own facilities, under strict government surveillance, where such an arrangement is shown to be in the best interests of the government

Furthermore, it is the intent of this standard that both performance[1/] and reliability be assessed in a test program of statistically valid length under combined, cyclic, and time-varying environmental conditions which simulate those expected in service use.

1.2.1 Alternative applications. This standard may be applied on a program requiring only the development of equipment where the final development model is to be used for reliability design qualification. However, this standard is not applicable to reliability growth testing. This standard may be applied on a pure production contract where the reliability design has already been qualified.

1.3 Classification. This standard is applicable to six broad categories of equipment, distinguished according to their field service applications:

Category 1	Fixed ground equipment
Category 2	Mobile ground vehicle equipment
Category 3	Shipboard equipment
	A. Sheltered
	B. Unsheltered
Category 4	Equipment for jet aircraft
Category 5	Equipment for turbo-prop and helicopter
Category 6	Air launched weapons and assembled external stores

1.4 Relationship to total reliability program. When testing in accordance with this standard, the minimum test program shall normally consist of a preproduction reliability qualification test, and a series of lot-by-lot production reliability acceptance tests or an all equipment production reliability acceptance test. However, prior to the initiation of these tests, and normally in conformance with the approved reliability program plan required by MIL-STD-785, several related tasks shall be completed, and approval obtained from the procuring activity. Appendix A describes the normal reliability program tasks for a military procurement, including full-scale development.

In practice, this would generally be accomplished by demonstrating an acceptable performance baseline through detailed performance measurement before the reliability tests are initiated. After completion of these detailed performance measurements, selected performance test criteria are then used during the reliability test to assure acceptable equipment performance. As a minimum, all failure indications that will cause initiation of corrective maintenance action in field service must be monitored.

2. APPLICABLE DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-C-45662	Calibration System Requirement

STANDARDS

MILITARY

MIL-STD-167-1	Mechanical Vibration of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited)
MIL-STD-721	Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors and Safety
MIL-STD-785	Reliability Program for Systems and Equipment
MIL-STD-810	Environmental Test Methods
MIL-STD-1399	Interface Standard for Shipboard Systems
MIL-STD-1543	Reliability Program Requirements for Space and Missile Systems
MIL-STD-1670	Environmental Criteria and Guidelines for Air Launched Weapons

HANDBOOKS

MILITARY

MIL-HDBK-108	Quality Control and Reliability - Sampling Procedures and Tables for Life and Reliability Testing (Based on Exponential Distribution)
MIL-HDBK-217	Reliability Prediction of Electronic Equipment

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AD-A005667	RADC-TR-75-22, RADC Non-electronic Reliability Notebook Revision (Part Failure Data, Section 2 of RADC-TR-69-458)

(Application for copies should be addressed to the National Technical Information Service, U.S. Department of Commerce, 5385 Port Royal Road, Springfield, VA 22151.)

GIDEP	Government Industries Data Exchange Program, Summaries of Failure Rates

(Application for copies should be addressed to the Fleet Analysis Center,GIDEP Operations Center, Naval Weapons Station, Seal Beach, Corona Annex, Corona, CA 91720.)

3. DEFINITIONS

3.1 General. Meanings of terms not defined herein are in accordance with the definitions in MIL-STD-721.

3.1.1 Contractor. Contractor includes Government or industrial activities developing/producing military systems and equipments.

3.1.2 Decision risks.

3.1.2.1 Consumer's risk (β). Consumer's risk (β) is the probability of accepting equipment(s) with a true MTBF equal to the lower test MTBF (θ_1). (The probability of accepting equipment(s) with true MTBF less than the lower test MTBF (θ_1) will be less than β.)

3.1.2.2 Producer's risk (α). Producer's risk (α) is the probability of rejecting equipment(s) with a true MTBF equal to the upper test MTBF (θ_0). (The probability of rejecting equipment(s) with true MTBF greater than the upper test MTBF will be less than α.)

3.1.2.3 Discrimination ratio (d). The discrimination ratio is one of the standard test plan parameters which establishes the test plan envelope. This ratio discriminates between θ_1 and θ_0.

$$d = \frac{\theta_0}{\theta_1}$$

3.1.3 Failure. Details involving failure criteria, to include required functions and performance parameter limits, must be stated in the equipment specification and test procedures as approved by the procuring activity. For test purposes, the following general definitions shall apply:

a. Failure is an event in which a previously acceptable item does not perform one or more of its required functions within the specified limits under specified conditions.
b. Failure is also the condition in which a mechanical or structural part or component of an item is found to be broken, fractured, or damaged which would cause failure under operational conditions.

3.1.4 Failure types.

3.1.4.1 Dependent failure. A failure caused by the failure of an associated item (dependent failures are not necessarily present when simultaneous failures occur).

3.1.4.2 Independent failure. A failure which occurs without being caused by the failure of other parts of the equipment under test, test equipment, instrumentation, or the test facility.

3.1.4.3 Intermittent failure. The momentary cessation of equipment operation.

3.1.4.4 Multiple failures. The simultaneous occurrence of two or more independent failures (when two or more failed parts are found during trouble shooting which cannot be shown to be interdependent, multiple failures are presumed to have occurred).

3.1.4.5 Pattern failures. The occurrence of two or more failures of the same part in identical or equivalent application which are caused by the same basic failure mechanism.

3.1.5 Failure classification. All failures are relevant and chargeable unless and until determined to be nonrelevant or nonchargeable or both by the procuring activity.

3.1.5.1 Relevant failure. All failures that can be expected to occur in subsequent field service. All relevant failures shall be used in computation of demonstrated MTBF.

3.1.5.2 Nonrelevant failure. A failure caused by a condition external to the equipment under test which is not a test requirement and not expected to be encountered in field service.

3.1.5.3 Chargeable failure. A relevant, independent failure of Contractor Furnished Equipment (CFE) under test, plus any dependent failures caused thereby, classified as one failure and used to determine contractual compliance with accept/reject criteria.

3.1.5.4 Nonchargeable failure. A relevant failure of CFE, caused by and dependent upon an independent failure of Government Furnished Equipment (GFE) or CFE of another contractor, and therefore not used to determine contractual compliance with accept/reject criteria.

3.1.5.5 Equipment design (ED). Failure in this area places the cause directly upon the design of the equipment; that is, the design of the equipment caused the part in question to degrade or fail, resulting in an equipment failure; for example, a circuit design which overstresses a part or other improper application of parts.

3.1.5.6 Equipment manufacturing (EM). These failures are caused by poor workmanship during the equipment construction, testing, or repair prior to start of test. This would also include possible overstressing of parts by the assembly process during the construction of the equipment.

3.1.5.7 Part design (PD). This category of failures consists of parts whose failures resulted directly from the inadequate design of the part. This would include such areas as the longevity of the part and its ability to withstand continuous temperature cycling.

3.1.5.8 Part manufacturing (PM). These failures are the result of poor workmanship during assembly of the part, inadequate inspection or testing.

3.1.5.9 Software errors (SE). These errors cause equipment failures when a computer was part of the equipment under test. NOTE: If software errors are corrected and verified during the test, such errors shall not be chargeable as equipment failures.

3.1.6 Mean-time-between-failures (MTBF).

3.1.6.1 Demonstrated MTBF ($\bar{\theta}$). The probable range of true MTBF under test conditions; observed MTBF within a stated confidence interval.

3.1.6.2 Observed MTBF ($\hat{\theta}$). Observed MTBF ($\hat{\theta}$) is equal to the total operating time of the equipment divided by the number of relevant failures.

3.1.6.3 Lower test MTBF (θ_1). Lower test MTBF (θ_1) is that value which is unacceptable and the standard test plans will reject, with high probability, equipment with a true MTBF that approaches θ_1 (θ_1 is equivalent to noncompliance with reliability requirements and will be included in Section 4 of the equipment specifications).

3.1.6.4 Upper test MTBF (θ_0). Upper test MTBF (θ_0) is an acceptable value of MTBF equal to the discrimination ratio times the lower test MTBF (θ_1). The standard test plans will accept, with high probability, equipment with a true MTBF that approaches θ_0 (both θ_0 and θ_1 should be identified in Section 3 of the equipment specifications).

3.1.6.5 Predicted MTBF (θ_p). Predicted MTBF (θ_p) is that value of MTBF determined by reliability prediction methods and is based on the equipment design and the use environment (θ_p should approach θ_0 in value to ensure with high probability that the equipment will be accepted during the reliability qualification test).

3.1.7 Mission profile. A mission profile is a thorough description of all of the major planned events and conditions associated with one specific mission. As such, a mission profile is one segment of a life profile (for example, a missile captive carry phase, or a missile free flight phase). The profile will depict the time span of the event, the expected environmental conditions, energized and non-energized periods, and so forth.

3.1.8 Operational life profile. An operational life profile is a thorough description of the events and conditions associated with an item of equipment from the time of final factory acceptance until its ultimate disposition (for example, factory-to-target sequence). Each significant operational life event, such as transportation, dormant storage, test and check out, standby and ready modes, operational deployment, mission profiles, and so forth, are addressed, including alternate possibilities. The profile depicts the time span of each event, the environmental conditions, operating modes, and so forth.

3.1.9 Procuring activity. Procuring activity, as used in this standard, refers to the government agency or the prime contractor in their dealings with their suppliers.

4. GENERAL REQUIREMENTS

4.1 General. The reliability qualification and acceptance tests are intregral parts of a reliability program such as MIL-STD-785, or MIL-STD-1543, and shall be planned and conducted in accordance with this standard. The required reliability testing shall be done under environmental conditions as specified in the test plan document and test procedures. Applicable reliability tests are described below.

4.1.1 First article (preproduction) reliability qualification test. The purpose of this test is to demonstrate that the equipment design will meet specified performance and reliability requirements under specified environmental conditions. These tests shall be conducted on items which are representative of production configuration in order to provide documented test results as inputs to the production decision.

4.1.2 Production reliability acceptance tests (sampling). These are a periodic series of tests conducted during the production run to ascertain whether equipment continues to meet specified performance and reliability requirements under specified environmental conditions. Unless otherwise specified in the contract, a production reliability acceptance test will normally be performed on each lot produced beginning with the first lot delivered after award of the production contract (see 5.5.1.2).

4.1.3 All equipment production reliability acceptance test. This test shall be specified when the contract requires that each and every equipment produced be subjected to a reliability acceptance test beginning with the first equipment delivered after award of contract. It may be used in lieu of the sampling type reliability acceptance test on production equipment.

4.2 Reliability test planning.

4.2.1 Integrated test planning. The reliability test plan document shall consider all other tests that are required by the contract in order to avoid duplication of test effort and to take advantage of the results of other tests. An overview of integrated test planning is presented in Appendix A.

4.2.2 Reliability test plan document. To implement the requirements of this standard, an overall reliability test plan document is required. This document shall include descriptions of all reliability qualification and acceptance tests and burn-in procedures. It shall reflect the requirements of the equipment specification and this standard (see 5.1.2). The reliability test plan document shall be submitted to the procuring activity for approval, prior to initiation of test.

4.2.3 Reliability test procedures. Detailed reliability test procedures shall be prepared for the reliability tests that are included in the reliability test plan document.

4.3 Test conditions/levels. The combination of environmental test conditions and levels to be applied under the provisions of this standard, and their variation as a function of test time, shall represent the field service environment and mission profile of the equipment under test.

4.3.1 Definition of test conditions. A specific profile of stresses to be applied during the test shall be specified in the equipment specification in accordance with one of the following procedures, listed in order of preference. It is the purpose of this standard to introduce more realistic environments during the reliability test, hence the preference order. When components of the system to be tested experience different environmental stresses due to location on the operational platform, a composite test profile shall be developed subject to the approval of the procuring activity when measuring vibration stresses. The mechanical impedance effects should be accounted for in establishing vibration levels. Stress types and levels applied during the test, or direction for ascertaining appropriate stress types and levels, shall be delineated in the solicitation by the procuring activity in the following priority.

a. Measured stress. Stress types and levels applied during the test shall be defined by the procuring activity and be based on measured environmental stresses at the proposed equipment location(s), in the proposed application(s) (operational platforms), and during performance of a typical mission profile(s).

b. Estimated stress. When measured stress data from the proposed applications are not available, measured environmental data from a similar location in a similar application for a similar mission profile may be used to determine the stress types and levels to be applied during the test.

c. Minimum stress. When the stress types and levels are not specified by the procuring activity, when measured environmental stresses for the proposed application are not available, and when measured environmental stresses from a similar application are not available for estimating, then the stress types and levels applied during the test shall be those delineated in Appendix B.

4.3.2 Combined environmental conditions/stresses. Unless otherwise specified, the stress types of TABLE I shall be combined in the same chamber at levels and rates of change appropriate to the measured stress data from the intended operational environment. FIGURE 1 presents a typical test cycle showing the timing of various conditions. The following stresses include the minimum factors to be considered.

4.3.2.1 Electrical stress. Electrical stress shall include equipment ON-OFF cycling, operation in accordance with its specified operating modes and duty cycles, and input voltage variance above and below the nominal value specified in the contract.

4.3.2.2 Vibration stress. Vibration test levels and profiles shall be tailored to the specific intended application of the equipment including its mounting location and the classification category of its use in the field. The minimum factors to be considered in the definition of realistic vibration stress shall be: (a) type of vibration (sinewave, complex or random); (b) frequency range; (c) amplitude; and (d) manner and axis of application. The intent of this requirement is to produce, in the equipment on test, a vibration response with a character, magnitude, frequency range, and duration similar to that produced by the field service environment and mission profile. The mechanical impedance effects (the interaction of equipment, fixture aircraft attachment structures, and shakers as they would influence the laboratory simulation of the effects of in-flight vibration environments) shall be accounted for in establishing vibration levels for all tests. As a minimum, the weight reduction criteria in Test Method 514.2 of MIL-STD-810 shall be applied.

4.3.2.3 Thermal stress. The thermal stress profile shall be a realistic simulation of the actual thermal environment that the equipment experiences in its service application. The minimum factors to be considered in the definition of realistic thermal stress shall be: (a) starting temperature (heat soak, cold soak) and turn-on (warm-up) time; (b) operating temperature (range, rate of change and frequency of change); (c) number of temperature cycles per mission profile; and (d) cooling airflow (rate and fluctuations).

4.3.2.4 Moisture stress. Moisture levels shall be sufficient during the temperature cycles to produce visible condensation and frosting or freezing when such conditions can be expected in field service. The humidity need not be held constant during the test cycle and may be increased to produce the desired result by injecting water vapor at appropriate times in the test cycle.

4.3.2.5 Procedures for deriving test conditions. The information and procedures presented in Appendix B shall be used to derive test conditions and stress levels if such data is not provided by the procuring activity.

TABLE I. Test conditions matrix.

Summary of Combined Environmental Test Condition Requirements

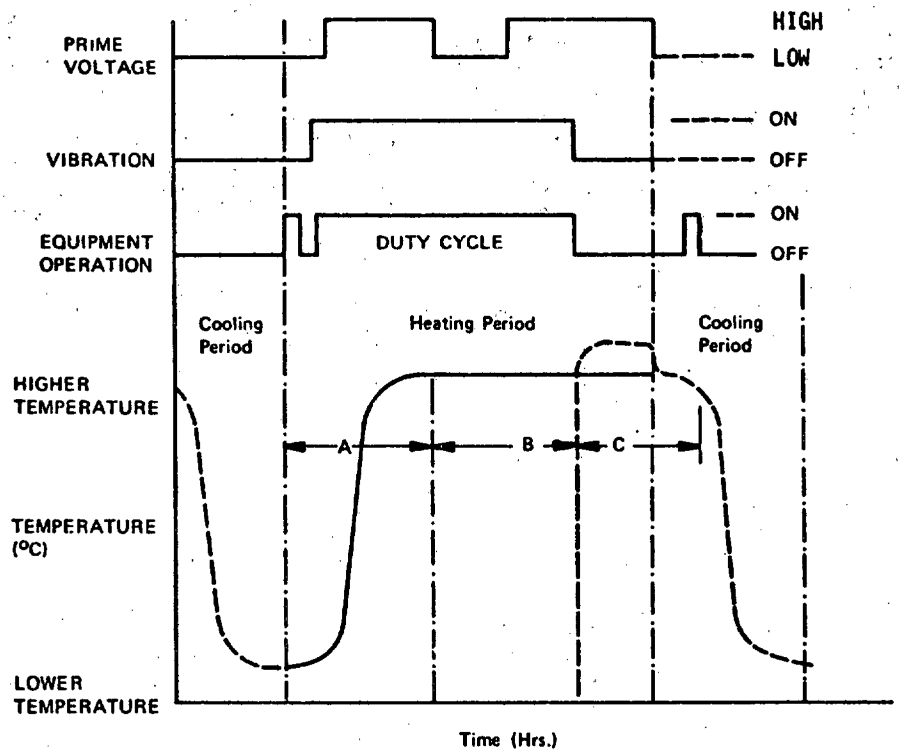
	FIXED GROUND	GROUND VEHICLE	SHIPBOARD SHELTERED	SHIPBOARD UNSHELTERED
ELECTRICAL STRESS				
Input voltage	Nominal + 5%-2%	Nominal ± 10%	Nominal ± 7%*	Nominal ± 7%*
Voltage cycle	high, nominal and low →	one per test cycle →	→	→
VIBRATION STRESS				
Type vibration	sinewave single frequency	swept-sine log sweep	swept-sine** continuous	swept-sine** continuous
Amplitude	(See APPENDIX B for	stress levels)		
Frequency range***	20 to 60 Hz	5 to 500 Hz		
Application	20 minimum per equipment	sweep rate 15 minimum once/hr	(See APPENDIX B →	→)
THERMAL STRESS (°C)	A B C ****	LOW HIGH	LOW HIGH	LOW HIGH
Storage temperature	- - -	-54 85	-62 71	-62 71
Operating temperature	20 40 60	-40 TO 55	0 TO 50 (CONTROLLED)	-28 65
Rate of change	- - -	5°/min.	5°/min.	5°/min.
Maximum rate of change	- - -	10°/min.	10°/min.	10°/min.
MOISTURE STRESS				
Condensation	none	1/test cycle	See APPENDIX B	1/test cycle
Frost/freeze		1/test cycle		1/test cycle

* See MIL-STD-1399
** See MIL-STD-167-1
*** Frequency tolerance ± 2 percent or ± 0.5 Hz for frequencies below 25 Hz.
****See 50.1.4 of Appendix B

TABLE I. Test conditions matrix (continued).

	AIRCRAFT				AIR-LAUNCHED WEAPONS AND ASSEMBLED EXTERNAL STORES
	FIGHTER	TRANSPORT, BOMBER	HELICOPTER	TURBO-PROP	
ELECTRICAL STRESS					
Input voltage range	nominal ± 10%	± 10%	± 10%	± 10%	± 10%
Voltage cycle	(nominal, high and low voltage, one cycle/thermal cycle or per APPENDIX B)				
VIBRATION STRESS					
Type vibration	random	random	swept-sine log sweep	swept-sine	swept-sine*** and random
Amplitude	(← SEE APPENDIX B →)				
Frequency range	20-2000 Hz	20-2000 Hz	5-2000 Hz****	10-2000 Hz	20-2000 Hz
Application	continuous	continuous	sweep rate 15 min. one/hr	continuous (see APPENDIX B)	continuous (see MIL-STD-1670)
THERMAL STRESS (°C)	LOW HIGH	LOW HIGH	LOW HIGH	LOW HIGH	LOW HIGH
Storage temperature (non-oper.)	-54 +71	-54 +71	-54 +71	-54 +71	-65 +71
Operating temperature range	(← See APPENDIX B →)				
Rate of change (min.)	5°/min.	5°/min.	5°/min.	5°/min.	5°/min.
Duration (nominal)	3 1/2 hours	3 1/2 hours	3 1/2 hours	3 1/2 hours	3 1/2 hours
MOISTURE STRESS					
Condensation	(1/test cycle - - - - - - - - - - - - - - - - - -)				
Frost/freeze	(1/test cycle - - - - - - - - - - - - - - - - - -)				

*** Frequency tolerance ± 2 percent or ± 5 Hz for frequencies below 25 Hz.
**** See 50.5.3 of Appendix B.



- - - - Equipment off (can be operated if required)
——— Equipment operated in accordance with duty cycle

} Applies to temperature cycle

A. Time for chamber to reach stabilization at higher temperature

B. Time of equipment operation at higher temperature

C. Optional Hot Soak and hot start-up checkout

FIGURE 1. Sample environmental test cycle.

4.4 Optional non-statistical production reliability acceptance test (sequential environment). The purpose of this test is to verify that production workmanship, manufacturing processes, quality control procedures, and the accumulation of Class II changes do not degrade the reliability which was found to be acceptable by the reliability qualification test. The test shall be applied to all production items with the item operating (power applied). The required test duration and number of consecutive failure free thermal test cycles (minimum of two) which each deliverable item must exhibit shall be specified by the procuring activity. The vibration, temperature cycling, and moisture environments together with any others which are deemed necessary may be applied sequentially. The equipment duty cycle and the sequence, duration, levels of the environments, and the vibration option to be used in this test require approval of the procuring activity, and shall be submitted in accordance with the test program requirements. The acceleration spectral density shall be in accordance with FIGURE 2. The vibration options are as follows.

4.4.1 Option I. Each equipment shall be exposed to 10 minutes of random vibration in one axis in accordance with FIGURE 2 with power applied. All failures occurring during this test shall be corrected. Tolerance for the random vibration shall be -3 dB measured in accordance with the random vibration test paragraph of Method 514.2 of MIL-STD-810.

4.4.2 Option II. Same as Option I except broadband/complex vibration may be used in lieu of random with a tolerance of -3 dB.

4.5 Statistical test plans (APPENDIX C).

4.5.1 General. These statistical test plans are to be used for estimation of true MTBF and determination of contractual compliance. The θ_0 and θ_1 are for the purpose of establishing accept/reject criteria and shall not be used for projection of equipment MTBF.

4.5.1.1 Standard test plans. The test plans of this section contain statistical criteria for determining compliance with specified reliability requirements. They are based on the assumption that the underlying distribution of individual times-between-failures will be exponential. The exponential assumption infers a constant failure rate; therefore, these test plans are not appropriate, and will not be applied for any test planned for the specific purpose of eliminating design defects or infant mortality type failures. The test plans are categorized as follows:

a. Fixed length test plans (Test Plans IXC through XVIIC and XIXC through XXIC)
b. Probability ratio sequential tests (PRST), (Test Plans IC through VIC)
c. Short run high risk PRST plans (Test Plan VIIC and VIIIC)
d. All equipment reliability test (Test Plan XVIIIC)

TABLES II, III, IV and V present the parameters of the standard test plans.

4.5.1.2 Operating characteristic and expected test time curves. Graphs presenting Operating Characteristic (OC) and Expected Test Time (ETT) curves are given in Appendix C. OC curves show the probability of acceptance versus the true MTBF (in multiples of θ_1 and θ_0) while ETT curves show the expected test time versus the true MTBF (in multiples of θ_1 and θ_0).

4.5.2 Requirements.

4.5.2.1 Selection of test plan. The test plans to be used in preproduction reliability qualification and production reliability acceptance tests shall be selected from Appendix C of this standard, specified in the contract and equipment specification, and described in detail in the reliability test plan document. In general:

a. A fixed length test plan must be selected when it is necessary to obtain an estimate of true MTBF demonstrated by the test, or when total test time must be known in advance. Therefore, a fixed length test plan should normally be selected for preproduction reliability qualification tests.

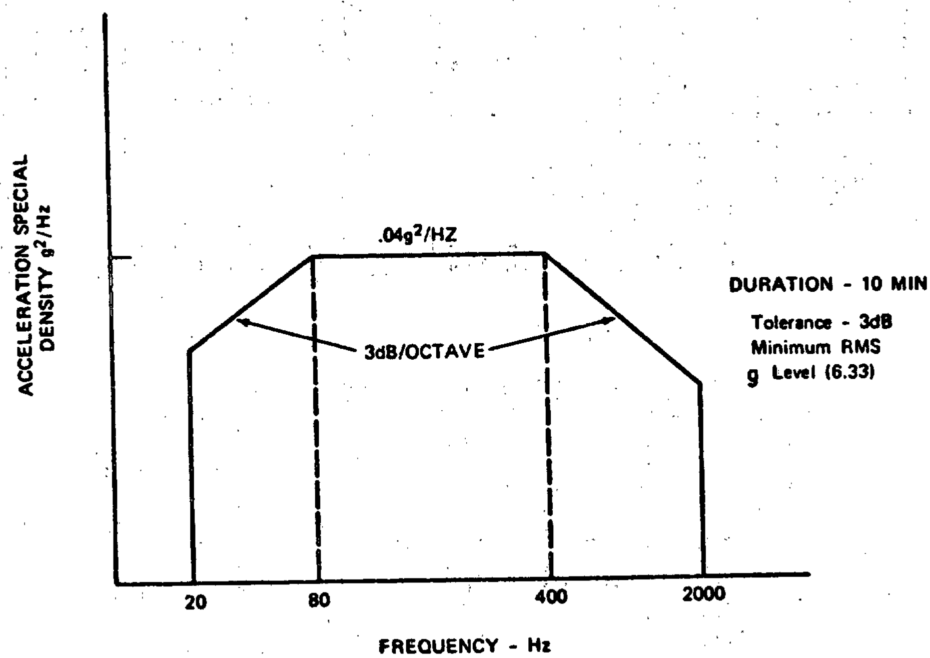


FIGURE 2. Random vibration acceptance test.

TABLE II. Summary of test plans (fixed length).

Test plan	True decision risks		Discrimination Ratio θ_0/θ_1	Test duration (multiples of θ_1)	Accept-reject failures	
	α	β			Reject (equal or more)	Accept (equal or less)
IXC	12.0%	9.9%	1.5	45.0	37	36
XC	10.9%	21.4%	1.5	29.9	26	25
XIC	17.8%	22.1%	1.5	21.1	18	17
XIIC	9.6%	10.6%	2.0	18.8	14	13
XIIIC	9.8%	20.9%	2.0	12.4	10	9
XIVC	19.9%	21.0%	2.0	7.8	6	5
XVC	9.4%	9.9%	3.0	9.3	6	5
XVIC	10.9%	21.3%	3.0	5.4	4	3
XVIIC	17.5%	19.7%	3.0	4.3	3	2

TABLE III. Summary of test plans (high risk fixed length)*.

Test plan	True decision risks		Discrimination Ratio θ_0/θ_1	Test duration (multiples of θ_1)	Accept-reject failures	
	α	β			Reject (equal or more)	Accept (equal or less)
XIXC	28.8%	31.3%	1.5	8.0	7	6
XXC	28.8%	28.5%	2.0	3.7	3	2
XXIC	30.7%	33.3%	3.0	1.1	1	0

*For more fully tailorable fixed-length test plans see APPENDIX C, Section 30.9.

TABLE IV. Summary of test plans (standard PRST).

Test plan	True decision risks		Discrimination ratio θ_0/θ_1	Accept-reject criteria Appendix C figure
	α	β		
IC	11.5%	12.5%	1.5	C-1
IIC	22.7%	23.2%	1.5	C-2
IIIC	12.8%	12.8%	2.0	C-3
IVC	22.3%	22.5%	2.0	C-4
VC	11.1%	10.9%	3.0	C-5
VIC	18.2%	19.2%	3.0	C-6

TABLE V. Summary of test plans (short run high risk PRST)*.

Test plan	True decision risks		Discrimination ratio θ_0/θ_1	Accept-reject criteria Appendix C figure
	α	β		
VIIC	31.9%	32.8%	1.5	C-7
VIIIC	29.3%	29.9%	2.0	C-8
XVIIIC	**	**	**	**

*For additional PRST plans with higher discrimination ratios and different risks refer to MIL-HDBK-108.

**Test Plan XVIIIC is the all equipment reliability acceptance test. See 4.5.4 for details.

b. A sequential test plan may be selected when it is only necessary to accept/reject predetermined MTBF values (θ_0, θ_1) with predetermined risks of error (α, β), and when uncertainty in regard to total test time is relatively unimportant. Therefore, either a fixed length or a sequential test plan may be selected for production reliability acceptance tests.

c. The all equipments hypothesis test plan may be selected when it is necessary to accept/reject every unit of the production run. CAUTION: The combination of an all equipments test plan with realistic combined-stress conditions may impact test and facilities and must be carefully evaluated.

4.5.2.2 Equipment performance. The parameters to be measured and the applicable acceptance limits shall correspond with the performance requirements of the equipment specification and shall be included in the test procedures (see 5.1.3).

4.5.2.3 Equipment quantity. The quantity of equipments to be tested, not necessarily simultaneously, shall be determined as required herein or as specified in the contract.

a. Sample size (reliability qualification). The sample size required for the qualification phase test plans shall be as specified in the contract, or as agreed by the contractor and the procuring activity.

b. Sample size (production reliability acceptance). The minimum number of samples to be tested per lot is 3 equipments unless otherwise specified by the procuring activity. The recommended sample size is 10 percent of the equipments per lot, up to a maximum of 20 equipments per lot.

c. All equipment production reliability acceptance. Under this test plan, all production equipment is subjected to the reliability acceptance test. All equipment acceptance testing (100 percent sample) should only be specified under exceptional circumstances, as determined by the requirements of safety or mission success.

4.5.2.4 Test length. When sequential test plans are specified, test length shall be planned on the basis of maximum allowable test time (truncation), rather than the expected decision point, to avoid the probability of unplanned and uncontrollable test cost and schedule overruns. Testing shall continue until the total unit hours together with the total count of relevant equipment failures permit either an accept or reject decision in accordance with the specified test plan, except the all equipment production reliability acceptance test. For the all equipment reliability test, testing shall continue until either a reject decision is made or all contractually required equipments have been tested. Equipment ON time (that is, equipment operating time) shall be used in determining test length and compliance with accept/reject criteria. Testing shall be monitored in such a manner that the times to failure may be recorded with reasonable accuracy. The monitoring instrumentation and techniques and the method of estimating MTBF shall be included in the proposed reliability test procedures. Each equipment shall operate at least one half the average operating time of all equipments on test.

4.5.2.5 Evaluation criteria. The test data on operational performance parameters, relevant failures, and total test time shall be evaluated against the approved test plan/procedures.

4.5.3 Sequential test plans. Probability ratio sequential test plans (PRST) are stated in detail in Appendix C. The accept-reject criteria for the standard sequential test plans are shown graphically and in tabular form in Appendix C along with the corresponding operational characteristic curves and the expected test time curves based on assumed value of true MTBF.

4.5.4 Test Plan XVIIIC (example - all equipment production reliability acceptance). This test plan shall be used when each unit of production (or preproduction equipment if approved by the procuring activity) equipment is to be given a reliability acceptance test. The plan is shown in FIGURE 3 and consists of a reject line and a boundary line. The reject and boundary lines are the same as the reject and accept lines of Test Plan IIIC but both lines are extended as far as necessary to cover the total test time required for production run. The equation of the reject line is $f_R = 0.72T + 2.50$ where T is cumulative test time in multiples of θ_1, f is cumulative number of failures. The plotting ordinate is failures and the abscissa is in multiples of θ_1, the lower test MTBF. The boundary line is 5.67 failures below and parallel to the rejection line. Its equation is $f_B = 0.72T - 3.17$.

4.5.4.1 Test duration. The test duration for each equipment shall be specified in the test procedure as approved by the procuring activity. The maximum duration may be 50 hours and the minimum 20 hours to the next higher integral number of complete test cycles. If a failure occurs in the last test cycle, the unit shall be repaired and another complete test cycle run to verify repair.

4.5.4.2 Evaluation. When this test plan is required, all production units shall be subjected to the environmental test conditions as set forth in the approved test procedure. Cumulative equipment operating time and equipment failure shall be recorded, plotted on chart of Test Plan XVIIIC, (FIGURE 3), and evaluated in accordance with the test procedure requirements based on the criteria of FIGURE 3 and 4.5.4.3 through 4.5.4.3.4.

4.5.4.3 Reject-accept criteria for Test Plan XVIIIC.

4.5.4.3.1 Acceptance. After being tested to the specified duration of 4.5.4.1, each equipment shall be considered acceptable after meeting the specified normal performance acceptance test, unless the reject line is reached.

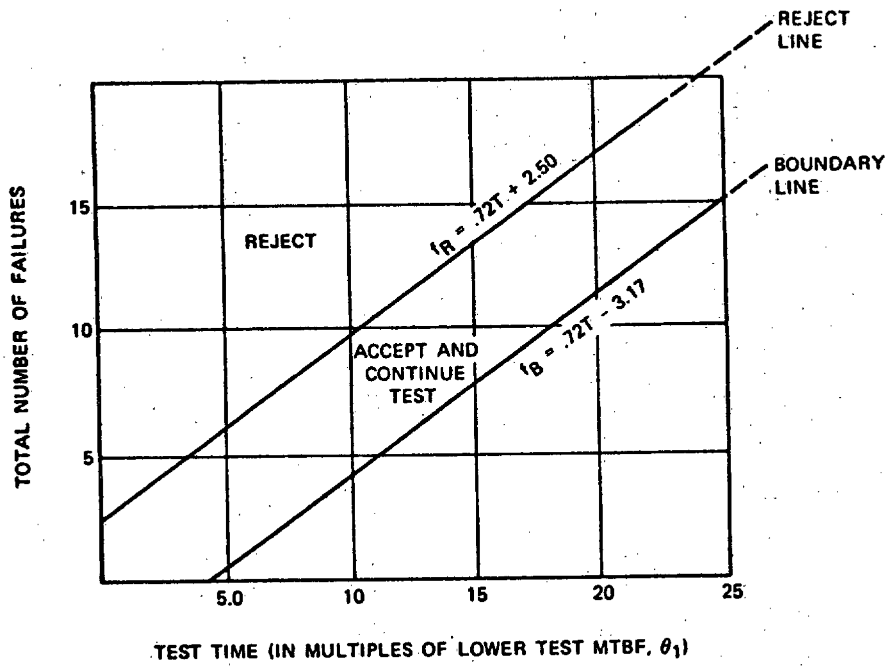
4.5.4.3.2 Rejection. Should a plot of failures versus time reach or cross the reject line, the equipments in test are no longer acceptable. The test shall then be terminated and corrective action in accordance with 5.9 shall be performed.

4.5.4.3.3 Reaching the boundary line [2/]. Should a plot of failures versus time reach the boundary line, the plotting of accumulated time shall follow the boundary line but censoring test time as necessary at each failure to maintain an accurate failure plot without crossing the boundary line. Thus the test time plot will not be true accumulated test time. All test time shall be recorded in the test log to maintain capability to determine true accumulated test time.

4.5.4.3.4 Alternative all-equipment production reliability acceptance test plans. An alternative all-equipment production reliability acceptance test plan may be used in lieu of Test Plan XVIIIC. That is, a unique test plan may be developed from any basic PRST plan, Test Plan IC through VIIIC, based on the actual test plan used during the qualification phase. A set of alternative two-line all equipment production reliability acceptance test plans are provided in APPENDIX C, Section 30.8.

4.6 MTBF estimation from observed test data. When the procuring activity must not only have a statistical basis for determining contractual compliance; and it must also have a basis for estimating the MTBF values to be expected in field service, a fixed length test plan must be used. All agencies conducting reliability tests under the provisions of this standard shall provide the procuring activity with current values of demonstrated MTBF ($\hat{\theta}$) as part of each required test report, when required.

[2/] If it is desired to maintain an accurate/true plot of accumulated test time and failures, this can be done on the same chart by continuing the plot into the region beyond the boundary line. However, to maintain the proper reject criteria, the first failure occurring after the boundary line is crossed must be shifted vertically to the boundary line to start a second plot (dotted line) within the Accept and Continue Test region, if failures occur often enough. If another failure does not occur for an extented period there would be no second plot and the original true plot would continue. Then the next failure would be plotted on the boundary line directly above the true plotted point (failure 7 of FIGURE 4). If several failures occur in rapid succession, the second plot (dotted line with failures vertically spaced at exact single failure intervals) would reach the reject line and testing would be terminated and corrective action would be taken. After approved corrective action is accomplished, the testing would resume and the true plot would continue as above. The cumulative number of failures and time as shown by the true plot would be read directly from the failure and time scales provided on the ordinate and abscissa. However, the failures plotted on the boundary line or above after the time plot crossed the boundary line would have to be labelled since the number could not be read off the ordinate. After a reject occurs and corrective action is approved, return the true plot to the boundary line. Continue the true plot on real time, and again numerically number the subsequent failures as shown on failure 16 of FIGURE 4.



Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Boundary Line	Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Boundary Line
0	N/A	4.40	9	9.02	16.88
1	N/A	5.79	10	10.40	18.26
2	N/A	7.18	11	11.79	19.65
3	.70	8.56	12	13.18	21.04
4	2.08	9.94	13	14.56	22.42
5	3.48	11.34	14	ETC	ETC
6	4.86	12.72	15	.	.
7	6.24	14.10	16	.	.
8	7.63	15.49	.	.	.

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE 3. Reject-accept criteria for Test Plan XVIIIC.

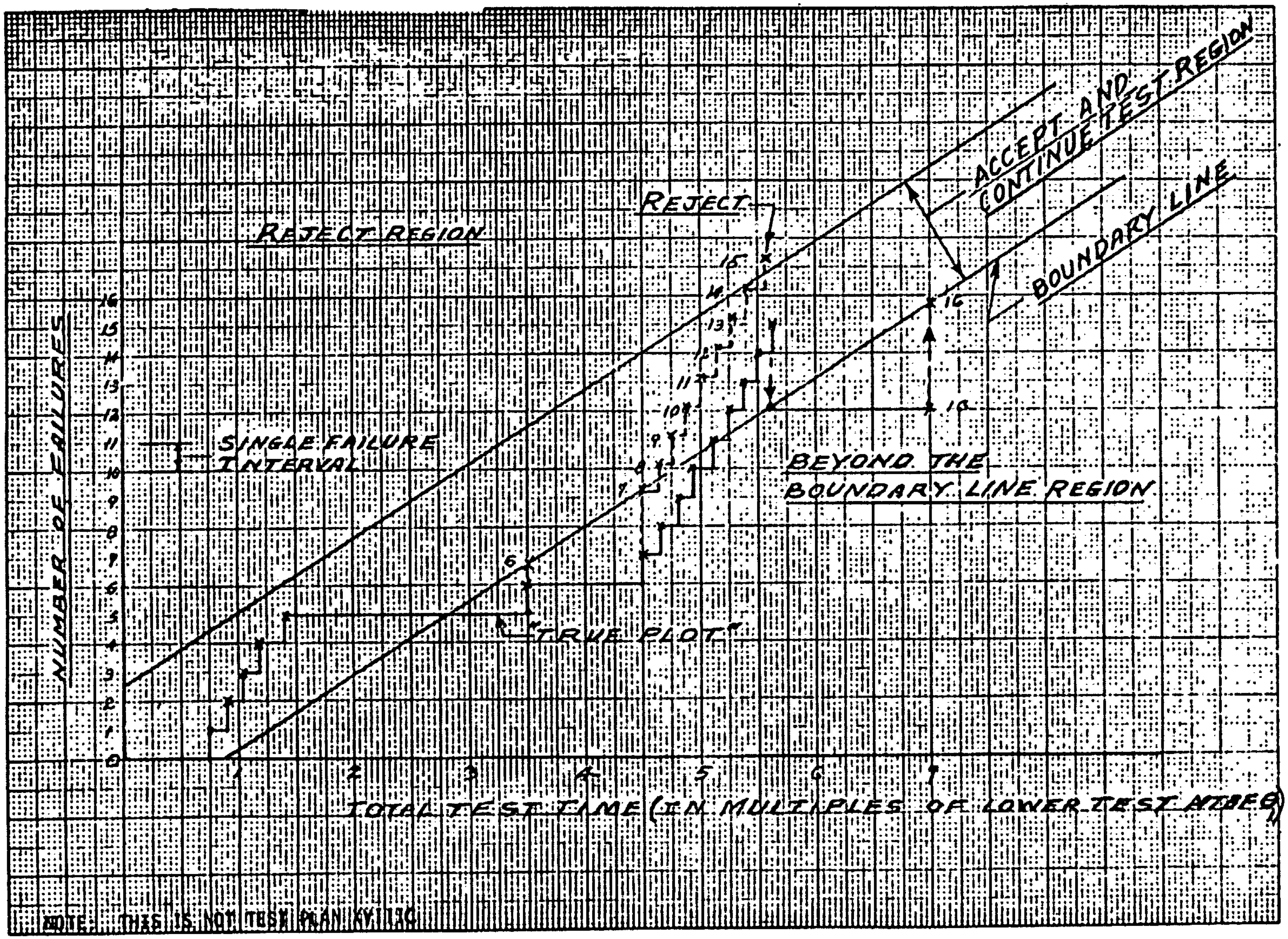


FIGURE 4. Boundary line criterion for reject-accept decision.

4.6.1 Exclusion of hypothesis test values. Since they are assumptions rather than test results, neither the upper test value (θ_0) nor the lower test value (θ_1) of any hypothesis test plan shall be used in estimation of demonstrated MTBF; rather the demonstrated MTBF ($\underset{\sim}{\theta}$) must be calculated from demonstrated test results. Producer's risk (α) and consumer's risk (β) are excluded from these calculations since they refer to the probability of passing or failing the test rather than to the probable range of true MTBF demonstrated during the test. However, the test parameters values (θ_0, θ_1, α, β) should be provided to assist in the understanding of how and why the data was gathered.

4.6.2 Specified confidence interval. In order to obtain an interval estimate of the demonstrated MTBF, the procuring activity must specify the confidence interval to be used. It is suggested that a confidence interval be selected such that its lower limit is equal to (100 - consumer's risk) percent - that is: 10 percent consumer's risk, 80 percent confidence interval; 20 percent consumer's risk, 60 percent confidence interval, 30 percent consumer's risk, 40 percent confidence interval.

4.6.3 MTBF estimation from fixed-length test plans. When a fixed-length test plan is specified, an interval estimate of the demonstrated MTBF of the test sample, under test conditions, shall be estimated within the specified confidence interval. When a test report is due, the agency conducting the test shall estimate the MTBF and confidence interval utilizing the following procedures.

4.6.3.1 MTBF estimation at failure occurrence. This calculation shall be made when a test is in process or has terminated in a reject decision.

a. Calculate the observed MTBF ($\hat{\theta}$) by dividing the total operating time of the equipment(s) at the occurrence of the most recent relevant failure by the number of relevant failures.

b. Enter TABLE VIa or FIGURE 5a with total failures and the specified confidence interval. Read out the lower and upper confidence multiplier for that number of failures.

c. Multiply observed MTBF ($\hat{\theta}$)(calculated by step a. above) by both the upper and lower confidence limit multipliers to obtain the lower and upper demonstrated MTBF values.

d. Record demonstrated MTBF as the specified percentage of confidence, followed by the lower and upper MTBF values in parenthesis: $\underset{\sim}{\theta}$ = XX percent (lower limit MTBF, upper limit MTBF). MTBF values will be rounded off to the nearest whole number.

e. If the values are not available in FIGURE 5a or TABLE VIa then the correct values can be obtained by computation as follows.

$$\text{MTBF multipler} = \frac{2r}{\chi^2\left(\frac{1+c}{2},\ 2r\right)}\text{, lower limits}$$

$$= \frac{2r}{\chi^2\left(\frac{1-c}{2},\ 2r\right)}\text{, upper limits}$$

where r = number of failures
χ^2 = Chi-square statistical distribution
c = confidence

For example: using 90 percent confidence interval, $c = .9$
Then $\frac{1+c}{2} = .95$ and $\frac{1-c}{2} = .05$

Example: The specified confidence interval is 80 percent. The 7th failure occurs at 820 hours total test time. Therefore, observed MTBF ($\hat{\theta}$) is 117.14 hours. Enter TABLE VIa (or FIGURE 5a) with 7 failures and the 90 percent upper and lower limits shows a lower limit multiplier of .665 and an upper limit multiplier of 1.797. The product of these multipliers with observed MTBF ($\hat{\theta}$)

yields a lower limit MTBF of 77.9 hours and an upper limit MTBF of 210.5 hours. There is an 80 percent probability that the true MTBF will be bounded by this interval (there is also a 90 percent probability that the true MTBF of the sample equipment is equal to or greater than 77.9 hours, and a 90 percent probability that it is equal to or less than 210.5 hours.) Demonstrated MTBF at this point in the test will be reported as: $\hat{\theta}$ = 80 percent (77.9/210.5) hours.

TABLE VIa. Demonstrated MTBF confidence limit multipliers, (for failure calculation).

TOTAL NUMBER OF FAILURES	CONFIDENCE INTERVALS					
	40%		60%		80%	
	70% LOWER LIMIT	70% UPPER LIMIT	80% LOWER LIMIT	80% UPPER LIMIT	90% LOWER LIMIT	90% UPPER LIMIT
1	.801	2.804	.621	4.481	.434	9.491
2	.820	1.823	.668	2.426	.515	3.761
3	.830	1.568	.701	1.954	.564	2.722
4	.840	1.447	.725	1.742	.599	2.293
5	.849	1.376	.744	1.618	.626	2.055
6	.856	1.328	.759	1.537	.647	1.904
7	.863	1.294	.771	1.479	.665	1.797
8	.869	1.267	.782	1.435	.680	1.718
9	.874	1.247	.796	1.400	.693	1.657
10	.878	1.230	.799	1.372	.704	1.607
11	.882	1.215	.806	1.349	.714	1.567
12	.886	1.203	.812	1.329	.723	1.533
13	.889	1.193	.818	1.312	.731	1.504
14	.892	1.184	.823	1.297	.738	1.478
15	.895	1.176	.828	1.284	.745	1.456
16	.897	1.169	.832	1.272	.751	1.437
17	.900	1.163	.836	1.262	.757	1.419
18	.902	1.157	.840	1.253	.763	1.404
19	.904	1.152	.843	1.244	.767	1.390
20	.906	1.147	.846	1.237	.772	1.377
30	.920	1.115	.870	1.185	.806	1.291

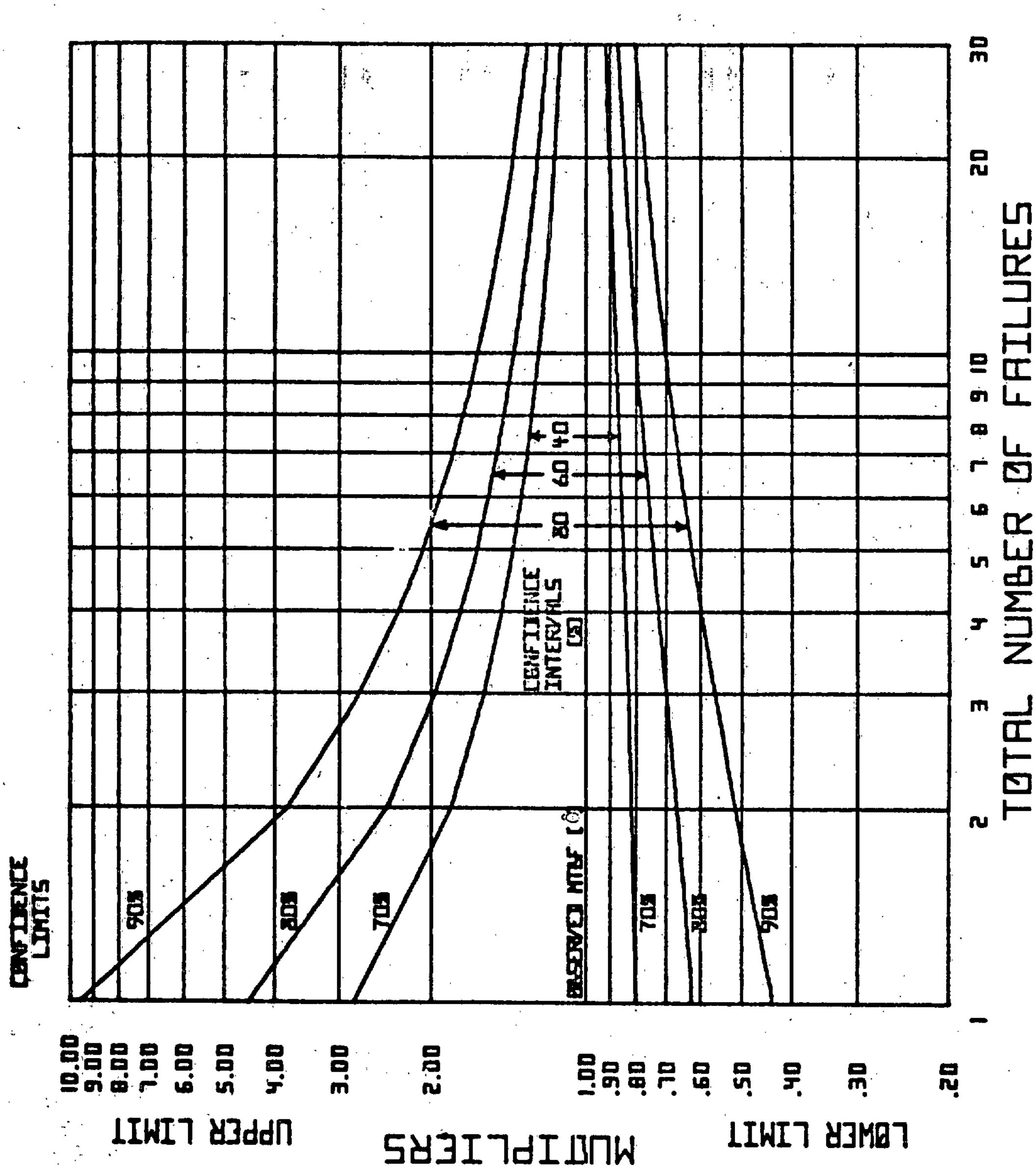


FIGURE 5a. Demonstrated MTBF confidence limit multipliers (for failure calculation).

4.6.3.2 MTBF estimation at acceptance. This calculation shall be made when the test is terminated in an accept decision.

a. Calculate the observed MTBF ($\hat{\theta}$) by dividing the total operating time of the equipment(s) by the number of relevant failures.

b. Enter TABLE VIb or FIGURE 5b with total failures and the specified confidence interval. Read out the lower and upper confidence multiplier for that number of failures.

c. Multiply observed MTBF ($\hat{\theta}$)(calculated by step a. above) by both the upper and lower confidence multipliers to obtain the lower and upper demonstrated MTBF values.

d. Record demonstrated MTBF as the specified percentage of confidence followed by the lower and upper MTBF values in parenthesis: $\underline{\theta}$ = XX percent (lower limit MTBF, upper limit MTBF). MTBF values will be rounded off to the nearest whole number.

e. If the values are not available in FIGURE 5b or TABLE VIb, then the correct values can be obtained by computation as follows:

$$\text{MTBF multiplier} = \frac{2r}{\chi^2\left(\frac{1+c}{2},\ 2r+2\right)}, \quad \text{lower limits}$$

$$= \frac{2r}{\chi^2\left(\frac{1-c}{2},\ 2r\right)}, \quad \text{upper limits}$$

where r = number of failures

χ^2 = Chi-square statistical distribution

c = confidence

Example: The specified confidence interval is 80 percent. The test reached an accept decision after 920 hours of testing with 7 failures occurring during that period. Therefore, observed MTBF ($\hat{\theta}$) is 131.43 hours. Entering TABLE VIb with 7 failures and the 90 percent upper and lower limits shows a lower limit multiplier of 0.595 and an upper limit multiplier of 1.797. The product of these multipliers with observed MTBF ($\hat{\theta}$) yields a lower limit MTBF of 78.2 hours and an upper limit MTBF of 236.2 hours. There is an 80 percent probability that the true MTBF is bounded by this interval (there is also a 90 percent probability that true MTBF of the sample equipment is equal to or greater than 78.2 hours, and a 90 percent probability that it is equal to or less than 236.2 hours). Demonstrated MTBF at the end of the test will be reported as: $\underline{\theta}$ = 80 percent (78.2/236.2) hours.

4.6.4 Projection of expected field MTBF. The contractor (or test agency, if other than the contractor) is responsible for providing demonstrated MTBF under test conditions. The procuring activity is responsible for projecting expected MTBF under field service conditions. However, this responsibility may be delegated to the contractor or test agency when so specified in the contract.

TABLE VIb. Demonstrated MTBF confidence limit multipliers (for time calculation).

TOTAL NUMBER OF FAILURES	CONFIDENCE INTERVALS 40%		60%		80%	
	70% LOWER LIMIT	70% UPPER LIMIT	80% LOWER LIMIT	80% UPPER LIMIT	90% LOWER LIMIT	90% UPPER LIMIT
1	0.410	2.804	0.334	4.481	0.257	9.491
2	0.553	1.823	0.467	2.426	0.376	3.761
3	0.630	1.568	0.544	1.954	0.499	2.722
4	0.679	1.447	0.595	1.742	0.500	2.293
5	0.714	1.376	0.632	1.618	0.534	2.055
6	0.740	1.328	0.661	1.537	0.570	1.904
7	0.760	1.294	0.684	1.479	0.595	1.797
8	0.777	1.267	0.703	1.435	0.616	1.718
9	0.790	1.247	0.719	1.400	0.634	1.657
10	0.802	1.230	0.733	1.372	0.649	1.607
11	0.812	1.215	0.744	1.349	0.663	1.567
12	0.821	1.203	0.755	1.329	0.675	1.533
13	0.828	1.193	0.764	1.312	0.686	1.504
14	0.835	1.184	0.772	1.297	0.696	1.478
15	0.841	1.176	0.780	1.284	0.705	1.456
16	0.847	1.169	0.787	1.272	0.713	1.437
17	0.852	1.163	0.793	1.262	0.720	1.419
18	0.856	1.157	0.799	1.253	0.727	1.404
19	0.861	1.152	0.804	1.244	0.734	1.390
20	0.864	1.147	0.809	1.237	0.740	1.377
30	0.891	1.115	0.844	1.185	0.783	1.291

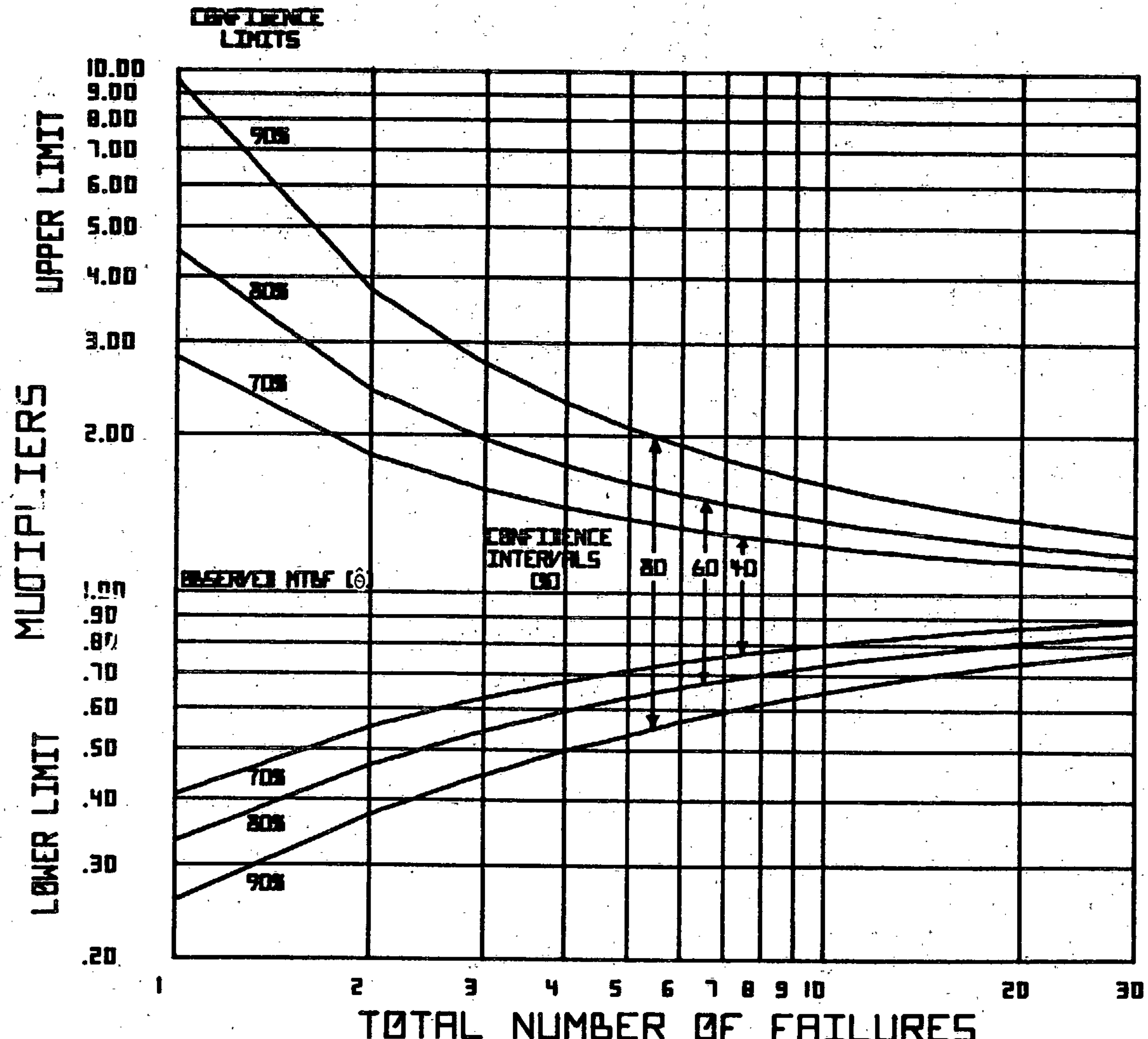


FIGURE 5b. Demonstrated MTBF confidence limit multipliers (for time calculation).

5. DETAILED REQUIREMENTS

5.1 Conditions preceding the reliability qualification test.

5.1.1 Reliability prediction. If directed by the procuring activity and if not already completed as required by other contractual documents, an updated reliability prediction of the test hardware configuration may be required prior to the start of reliability testing. Failure rate data sources shall be MIL-HDBK-217, RADC-TR-75-22 (AD-A005667) and GIDEP (in the listed order of priority). Other failure rate data sources, including contractor inhouse data, shall require procuring activity approval. The prediction report shall be approved by the procuring activity prior to the pretest readiness review. In the event that the design proposed for testing displays an undue risk (θ_p low compared with θ_0), the design is not ready for test.

5.1.2 Reliability test plan document. The reliability test plan document shall be completed and approval obtained from the procuring activity early in the program, in accordance with the CDRL, to allow adequate time for the preparation and approval of test procedures prior to the reliability qualification test. See Data Item Description entitled Plan, Reliability Test for List of Items to be covered, DID number DI-R-7033.

5.1.3 Reliability test procedures. After approval of the reliability test plan document, the (contractor or independent) test agency shall prepare detailed test procedures. These shall be submitted to the procuring activity for approval, in accordance with the contract data requirements list (CDRL) (DD1423), before the start of the applicable test. Appendix D presents considerations for use in the preparation of these procedures.

5.1.4 Reliability test plan and procedures. At the option of the procuring activity, the reliability test plan document and the test procedures may be combined in one document entitled Reliability Test Plan and Procedures and submitted for approval in accordance with the CDRL.

5.1.5 Thermal survey. Unless previously accomplished, a thermal survey shall be performed on the equipment to be tested under the temperature cycle and duty cycle required in the reliability qualification test procedures. The reliability test sample should not be used in the thermal survey; otherwise the time thus accumulated constitutes a mandatory test screen on all production equipments (see 5.1.8). However, if due to equipment availability and with the procuring activity approval of such use, the time thus accumulated shall not constitute a mandatory test screen on all production equipment. The thermal survey shall be utilized for identification of the component of greatest thermal inertia and the establishment of the time temperature relationships between it and the chamber air. These relationships shall be used for determining equipment thermal stabilization during the test. The lower test level temperature stabilization takes place when the temperature of the point of maximum thermal inertia is within 2^oC of the lower test level temperature and its rate of change is less than 2^oC/hour. Upper test level temperature stabilization takes place when the rate of change of the point of maximum thermal inertia at the upper temperature limit is less than 2^oC/hour. Deviations may be granted for large test items. The techniques and results of the thermal survey shall be described, plotted, and submitted to the procuring activity for approval as required by the CDRL (DD1423), prior to initiation of reliability testing. The equipment thermal survey need be made only once for each identical equipment type representative of the manufacturer's normal production under the current production.

5.1.6 Vibration survey. Unless previously accomplished, a vibration survey shall be performed on Category I equipment (fixed ground) to search for resonant conditions between 20 and 60 Hz in order that they may be avoided during the fixed frequency vibration test for the reliability qualification test.

5.1.7 Test unit configuration. All test units shall be representative of the design approach approved at the Critical Design Review (CDR), and shall be the best available representation of the production configuration. Normally, all development test shall have been completed, and any design, process or specification changes resulting therefrom shall have been incorporated prior to the start of preproduction qualification tests.

5.1.8 Pretest readiness review[3/]. After procuring activity approval of the reliability test procedure and before start of the reliability test, the contractor shall convene a reliability test readiness review at the contractor's test facility. The purpose will be to review the prerequisites and to ensure compatibility and understanding of all test requirements set forth in the approved test plan/procedures. The contractor shall notify the procuring activity a minimum of 10 days before conduct of the review to enable procuring activity representation. The results of the pretest readiness review shall be documented by the contractor and made available to the procuring activity at least two days prior to the start of the test.

5.1.9 Preconditioning burn-in. Equipment used in the reliability tests must be representative of follow-on production. Equipments submitted for reliability testing shall receive no special preconditioning other than that which will be used for preconditioning of all production equipment. This preconditioning may be at the option of the contractor unless specifically required by contract. This applies to all preconditioning at all levels of assembly. Failures occurring during preconditioning are not chargeable for accept/reject decisions, but shall be recorded, analyzed in accordance with 5.6.2 and appropriate repair action taken. Repair shall be limited to that necessary to restore equipment to its pre-failure condition in accordance with drawing requirements. The last repair during burn-in shall be verified by a failure-free operating period of at least two complete test cycles (vibration and temperature) unless otherwise specified by the procuring activity. The preconditioning burn-in and the environmental stresses applied shall be approved by the procuring activity as part of the reliability test procedures (see Appendix D). Contractors shall have the option of preconditioning equipment prior to specified preconditioning. However, the contractor shall provide the details of the additional preconditioning test procedure in the test procedure document. The additional preconditioning shall be applied to all units of production and no changes in the procedure shall be permitted unless approved by the procuring activity. The following summarizes and notes additional considerations:

a. The necessity of burn-in to stabilize failure rate before test.
b. All equipment, including test units, to receive same burn-in.
c. Failures during burn-in do not count for accept/reject, but are to be eliminated under the Correction of Defects clause.
d. Duration of burn-in and failure-free interval to be determined, if any
e. Environmental stresses selected to reveal maximum defects in minimum time - without causing failure modes that do not appear in field service - rather than for precise simulation of the operational environment.

5.2 Inspection and surveillance. Surveillance visits to the contractor's facility, use of procuring activity inspection personnel, and any other appropriate means for assuring compliance with reliability requirements shall be made by the procuring activity. The contractor shall provide necessary administrative support, as required in the contract, to permit such personnel to properly perform their authorized duties.

5.3 Equipment test cycle. During reliability testing, the equipment on test shall be subjected to repetitive test cycles similar to FIGURE 1. Typical combinations of environments and test levels are presented in Appendix B for the various categories of equipment. The specific test values and cycle durations shall be specified in the detailed test procedures approved by the procuring activity.

5.4 Test facilities. Test facilities shall be capable of maintaining conditions specified for the applicable test environments. Test instrumentation shall measure equipment characteristics to the specified accuracy for the duration of the test (see Appendix E).

5.4.1 Calibration. Both the environmental and monitoring test instrumentation shall be determined to be in proper operating condition and calibration prior to the start of the test and shall be checked and maintained as specified in MIL-C-45662.

[3/] This review shall be conducted when specified for U.S. Army procurements.

5.5 Test implementation.

5.5.1 Selection of equipment.

5.5.1.1 Reliability first article (preproduction) qualification test. The equipment used for reliability qualification testing shall represent the production design configuration. Normally, at least two equipments are used, depending on equipment availability, schedule and test duration.

5.5.1.2 Reliability production acceptance test. If the contract or order does not define what constitutes a lot, then one month's production shall constitute a lot; however, if less than three equipments are produced during a month, then the lot shall consist of two or more months' production, the actual quantity to be negotiated with the procuring activity. For the all equipments tests, all production units shall be tested. For a sampling type test, the equipments to be tested shall be representative of the entire lot from which they are selected and selections shall be specified by the procuring activity. All equipments selected shall have been subjected only to that preconditioning applied to all items of equipment submitted for acceptance and shall have passed the individual tests described in the acceptance test portion of the normal production test specification. Equipments used for special tests, which are not a part of the production process, shall not be considered for the reliability tests. If specifically authorized by the procuring activity, equipments used for the thermal survey and vibration survey may be used for reliability tests.

5.5.2 Installation of equipment. The equipment to be tested shall be installed in the test facility in a manner representative of the field installation with the necessary instrumentation to meet the requirements for the test and to provide for the safety of the equipment, the test facility, and the personnel. Calibration and adjustment of the test samples shall be limited to those specified in the applicable detailed test procedures.

Caution: Placement of the test samples in the chamber can have an effect on the thermal characteristics of the test samples.

5.5.3 Measurement. The equipment performance parameters to be measured and the frequency of measurement shall be specified in the test procedures (see Appendix D). If the value of any required performance parameter is not within specified limits, a failure shall be recorded. If the exact time of failure cannot be determined, the failure shall be presumed to have occurred at the last recorded observation or successful measurement of that same parameter. Observations and measurements shall be made and recorded during different portions of the test cycle (A and B of FIGURE 1) with at least one set of measurements recorded when the equipment is first energized after any specified equipment start-up period.

5.5.4 Testing sequence. The testing sequence shall be as specified in the test procedure. This sequence shall be repeated until a failure occurs or the total test time is completed. When a failure occurs, the equipment shall be repaired and testing resumed, preferably in that part of the sequence where the failure occurred.

5.6 Failure actions. On the occasion of a failure, entries shall be made on the appropriate data logs and the failed equipment shall be removed from test and repaired with minimum interruption to the equipments continuing on test. Failure actions shall be defined in the test plan. For guidance, the following shall be considered in defining the specific actions of failure in the test plan. All failed parts shall be replaced; any part which has deteriorated but does not exceed specified tolerance limits shall not be replaced unless that part is known to have been stressed beyond its rated capability due to another part failing. After a failed and repaired equipment has been returned to operable condition, it shall be returned to test with appropriate entries in the data logs, and with minimum interruption to the other equipment continuing on test. The absence of one or more equipments for the purpose of failure repair shall not affect the ability to make decisions from log data. Failures discovered during equipment or sub-element operation for troubleshooting purposes, if not dependent on the basic failure, shall be categorized and recorded and if not determined to be non-relevant, shall be considered as relevant multiple failures having occurred at the same time as the basic failure. Modules and subassemblies shall not be permanently replaced unless they have previously been designated as disposal at failure items or as approved by the procuring activity. Temporary replacement of plug-in items may be authorized by the procuring activity during troubleshooting and repair periods, when necessary to permit reliability test continuation. Piece parts removed during repair shall not be reinstalled when the reliability of the equipment could be impaired as judged by appropriate quality assurance and workmanship practices.

5.6.1 Failure categories. All failures shall be classified as relevant or nonrelevant. Relevant failures shall be further classified as chargeable or nonchargeable. Classification of failures will be proposed by the contractor and forwarded to the procuring activity for approval as part of the test plan. See FIGURE 6 for example of failure categories.

5.6.1.1 Relevant failures.

a. Intermittent failures.
b. Unverified. Failures which cannot be duplicated or are still under investigation, or for which no cause could be determined.
c. Verified. Failures not otherwise excluded under 5.6.1.2.

5.6.1.2 Nonrelevant failures.

a. Installation damage.
b. Accident or mishandling.
c. Failures of the test facility or test-peculiar instrumentation.
d. Equipment failures caused by an externally applied overstress condition in excess of the approved test requirements.
e. Normal operating adjustments (non-failures) as prescribed in the approved equipment operating instructions.

5.6.1.3 Chargeable failures.

a. Intermittent failures (IF).
b. Unverified failures (UF).
c. Independent failures to include:
(1) Equipment design (ED).
(2) Equipment manufacturing (EM).
(3) Part design (PD).
(4) Part manufacturing (PM).
(5) Software errors (SE). NOTE: If software errors are corrected and verified during the test, such errors shall not be chargeable as equipment failures.
(6) Contractor-furnished (CF) operating, maintenance or repair procedure that cause equipment failure.

5.6.1.4 Nonchargeable failures.

a. Nonrelevant failures.
b. Dependent failures counted with the independent failure that caused them.
c. Failures induced by GFE equipment, operating, maintenance or repair procedures.
d. Failures of items having a specified life expectancy, when operated beyond the defined replacement time of that item.

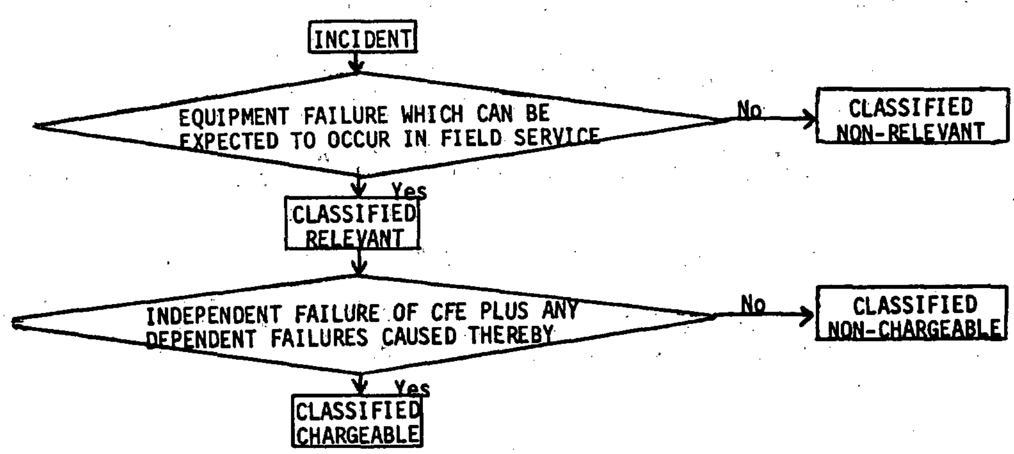


FIGURE 6. Example of failure categories.

5.6.2 Analysis of failures. Every equipment or part failure observed including Government Furnished Equipment (GFE) or parts which are tested with the equipment under test, shall be investigated and analyzed to determine the cause of failure. Analysis of GFE failures shall be limited to verifying that the contractor's equipment under test did not cause the failure in the GFE and the procuring activity shall be so notified. The investigation and analysis of other than GFE failures shall consist of any applicable method (such as test, application study, dissection, X-ray analysis, microscopic analysis, or spectrographic analysis) which may be necessary to determine the cause of failure. It is the objective that no part or unit may be removed from any equipment involved in the reliability test unless such part or unit can be demonstrated by the contractor to be overstressed or outside of specification tolerances. However, when no part or unit can be demonstrated to be beyond specification limits, whether deteriorated or otherwise, the equipment failure must be classified as a relevant failure and shall be counted in the total number of equipment failures. Details of the circumstances shall be referred to the design or quality control activity for close study. Repair where a good part was replaced made under the above conditions, shall not be counted as a relevant failure, if the original failure symptom recurs during the next measurement opportunity at the same environment in which it failed originally, and if the erroneously replaced part cannot be confirmed to be defective.

5.7 Determination of compliance.

5.7.1 General. Compliance shall be determined by the accept/reject criteria of the approved test plan and procedure. Compliance shall be reviewed after each equipment failure is categorized by the procuring activity or at any other appropriate time. The basis for compliance shall be the total count of chargeable equipment failures and the test time, using the applicable accept/reject criteria. Test time is equipment operating time or exposure time, as appropriate, and shall be recorded as accumulated unit test hours. A decision to accept, continue testing, or reject shall result in the actions delineated in 5.7.2 to 5.7.5. Unless otherwise specified by the procuring activity, an accept decision shall not be made at a point where any single equipment of the demonstration sample shall have accumulated less than one-half of the average creditable test time of all samples. Once classified as chargeable by the procuring activity, failures shall not be reclassified as nonchargeable on the basis of a recommended corrective action.

5.7.2 Accept in reliability qualification phase. When an accept decision is reached by satisfying requirements in accordance with the specified test plan and procedure for the reliability qualification test, the equipment design has been qualified for production with respect to reliability. This does not mean that θ_0 has been achieved, but that there is a high probability that θ_1 has been exceeded.

5.7.3 Accept in production reliability acceptance phase.

5.7.3.1 Production lot sampling test. If an accept decision is reached on a lot sampling basis by satisfying the requirements of the specified test plan and procedures, all equipments in that production lot are accepted. The reliability test units shall be resubmitted to their individual performance acceptance tests. When refurbishment of test units is required, see 5.11.

5.7.3.2 All equipment reliability test. Under all equipment production reliability acceptance testing, all equipments that complete their specified test duration satisfactorily shall be accepted until the reject line of Test Plan XVIIIC is crossed (see 4.5.4).

5.7.4 Reject in reliability qualification phase. If the qualification test results in a reject decision, the equipment design has not been qualified for production with respect to reliability.

5.7.5 Reject in reliability production acceptance phase.

5.7.5.1 Production lot sampling test. If a reject decision is reached on a lot sampling basis, all equipments in that lot are noncompliant, and further acceptance shall be discontinued. Corrective action shall be as specified for non-compliance (see 5.9).

5.7.5.2 All equipment reliability test. If all equipment production reliability acceptance testing results in a reject decision by crossing the reject line of Test Plan XVII, further acceptance shall be discontinued. Corrective action shall be as specified for non-compliance (see 5.9).

5.8 Verifying repair. The contractor shall verify the effectiveness of the repair of failed equipment before resuming reliability testing.

5.9 Corrective action. Corrective actions for all failures shall be determined and recommended to the procuring activity. In the event of non-compliance (reject decision), or when a pattern failure occurs, the contractor shall immediately notify the procuring activity and promptly develop and submit a corrective action plan based on the order in CDRL (DD 1423). In the event of non-compliance (reject decision), the corrective action plan shall address all failures that have occurred during reliability testing. Changes of specified performance or required reliability characteristics of the equipment are not corrective actions. Implementation of the plan is contingent upon the approval of the procuring activity. See Data Item Description entitled Plan, Corrective Action for List of Items to be covered, DID number DI-R-7038.

5.10 Preventive maintenance. Preventive maintenance procedures specified for the equipment during service use and listed in the approved test procedures shall be performed during the reliability test. No additional preventive maintenance is allowed during the reliability test or during equipment repair unless specifically authorized by the contract with respect to the test. Preventive maintenance may be performed on the test facility as necessary to ensure completion of the reliability test.

5.11 Restoration of tested equipments. Upon completion of reliability tests, equipment shall be refurbished as necessary to return to satisfactory operating condition unless other disposition is directed by contract. Failed parts shall be replaced and parts which have deteriorated but do not exceed specified tolerance shall be replaced unless the procuring activity directs otherwise. The equipments shall successfully complete the acceptance test procedures prior to shipment. Unless otherwise specified by contract, the contractor shall furnish all replacement parts required for refurbishment.

5.12 Test records. Records addressing both burn-in and test shall be maintained continuously as specified in the approved test procedure. These records shall be in general accord with the recommendations presented in Appendix D and shall include:

a. Test log and data record
b. Equipment failure record
c. Failure summary report
d. Failure tag
e. Failure identification/analysis report
f. Failure classification

5.13 Reliability test reports. No reports are required by this document unless they are specified by the contract or order. The contract or CDRL (DD 1423) will specify reports in accordance with MIL-STD-781, the following shall apply:

5.13.1 Periodic summary. See Data Item Description entitled Reports, Reliability Test and Demonstration for List of Items to be covered, DID number DI-R-7034.

5.13.2 Final report. The final report shall be prepared after completion of equipment testing. This report shall summarize all test results obtained during the contract and shall include, but not be limited to, a failure summary and analysis, and a general reliability analysis.

5.13.2.1 Failure summary and analysis. Failure analysis of items shall cover the detailed diagnosis of each failure and include basic corrective actions identified, indicated or accomplished. Each failure analysis shall be cross referenced to the consecutive failure numbers. Full supporting data for all failures classed as non-relevant or test equipment shall be included. See Data Item Description entitled Report, Failure Summary and Analysis for List of Items to be covered, DID number DI-R-7041.

5.13.2.2 General reliability analysis of equipment. The final report shall include a general analysis of the equipment reliability. A summary of pertinent data and information shall be presented. Normally, graphs of the accept/reject criteria with test data plotted thereon; of failures by equipment serial number plotted against time; and of observed MTBF plotted against time (for the duration of the contract) are appropriate. All pertinent factors should be analyzed carefully and appropriate conclusions or inferences including effects of test environments presented to the procuring activity. An analysis of failures should include categorization as described in 5.6.1.1 and 5.6.1.2.

6. NOTES AND CONCLUDING MATERIAL

6.1 Intended use. This standard is used to measure contractual compliance with specified reliability requirements.

6.2 Ordering data. Procurement documents should specify the following:

a. Title, number, and date of this standard
b. Application (see 1.2)
c. Classification (see 1.3)
d. When a production reliability acceptance test is not performed on each lot produced (see 4.1.2)
e. Specific profile of stresses to be applied during the test (see 4.3.1)
f. When stress types shall not be combined in the same chamber (see 4.3.2)
g. The required test duration and number of consecutive failure free thermal test cycles (see 4.4)
h. Test plans to be used in preproduction reliability qualification and production reliability acceptance test (see 4.5.2.1)
i. Sample size required for the qualification phase test plans (see 4.5.2.3)
j. If other than 3 equipments per lot for the production reliability acceptance test (see 4.5.2.3)
k. Confidence interval (see 4.6.2)
l. If the last repair during burn-in is not to be verified by a failure-free operating period of at least two complete test cycles (vibration and temperature (see 5.1.9)
m. Preconditioning burn-in and environmental stresses (see 5.1.9)
n. If an accept decision shall be made at a point where any single equipment of the demonstration sample shall have accumulated less than one-half of the average creditable test time of all samples (see 5.7.1).
o. If contractor is not to furnish all replacement parts required for refurbishment (see 5.11)

6.3 Data requirements. Deliverable data required by this standard is cited in the following paragraphs:

Paragraph	Data Requirement	Applicable DID
5.1.2	PLAN, RELIABILITY TEST	DI-R-7033
5.1.3	PROCEDURES, RELIABILITY TESTS	DI-R-7035
5.1.5	REPORT, THERMAL SURVEY	DI-R-7036
5.1.6	REPORT, VIBRATION SURVEY	DI-R-7037
5.1.9	REPORT, BURN-IN TEST	DI-R-7040
5.9	PLAN, CORRECTIVE ACTION	DI-R-7038
5.13.1	REPORTS, RELIABILITY TEST AND DEMONSTRATION	DI-R-7034
5.13.2.1	REPORT, FAILED ITEM ANALYSIS	DI-R-7039
5.13.2.1	REPORT, FAILURE SUMMARY AND ANALYSIS	DI-R-7041

6.4 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

Custodians:

Army-EL
Navy-EC
Air Force-11

Preparing Activity:
NAVY-EC
(Project No. RELI-0004)

Review Activities:

Army-EL, MI, AR, AV
Navy-AS, SH, OS
Air Force-01, 10, 13, 17, 19, 16, 18
Navy-AS, SH, OS

User Activities:

Army-AT, WC, ME
Navy-
Air Force-

APPENDIX A *

RELIABILITY PROGRAM OVERVIEW AND THE ROLE OF RELIABILITY TESTING

10. GENERAL

10.1 Scope. This appendix describes briefly a reliability program of the type desired by the implementation of MIL-STD-785, applicable to development and production, including the necessary environmental considerations and providing the program relationships to reliability qualification and acceptance testing.

10.2 Purpose. The purpose of this appendix is to provide the interrelationship of the reliability qualification and acceptance testing to the total reliability program, and to highlight those reliability activities that must be completed prior to such testing, if it is to be effective.

10.3 Program goals. The goal of the reliability program is to provide a high degree of confidence (both analytically and through testing) that the subject equipment will achieve satisfactory reliability values in field service. A time-phased program which toward achieving this goal is described in the following sections, and illustrated in TABLE A-I. This appendix does not include the necessary management structure or management tasks required to assure effectiveness of the reliability program efforts, nor any contractually required reporting efforts.

20. APPLICABLE DOCUMENTS

MIL-STD-810	Environmental Test Methods

30. RELIABILITY PROGRAM ELEMENTS

30.1 Requirements definition. Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions. It is fundamental that the requirements for the item be fully defined, including the desired reliability, the definition of performance, the required intervals, and the operational conditions. Representative tasks are shown in TABLE A-I.

30.2 Design support. Beginning with the earliest engineering phase of the equipment design, iterative reliability design support tasks should be initiated. These tasks must be planned and scheduled to provide design criteria in a timely manner, and to assess the potential reliability of the design as it progresses. Representative tasks are shown in TABLE A-I.

30.3 Development support. During the development phase, the reliability model should be updated and production model defined. The Failure Modes, Effects and Criticality Analysis (FMECA) should also be updated. See TABLE A-I for representative tasks.

30.4 Qualification support. During all phases of the program, reliability support should be provided for the planning of tests, failure recurrence control, assessment of test results, monitoring of reliability growth, and other supportive tasks, of which representative examples are shown in TABLE A-I.

30.5 Production support. During the production and deployment phase of the equipment life cycle, reliability support should be provided for monitoring of failures and failure recurrence control, conduct of the reliability and environmental acceptance tests, and feedback of stockpile and deployed equipment data for product improvement. Typical tasks are shown in TABLE A-I.

* THIS APPENDIX WILL BE DELETED AND INCORPORATED INTO MIL-STD-785 WHEN IT IS CIRCULATED FOR COORDINATION.

TABLE A-I. Example of time-phased reliability program activities.

	0	I	II		III
PROGRAM PHASE	CONCEPTUAL PHASE	DEMONSTRATION AND VALIDATION PHASE	FULL SCALE ENGINEERING DEVELOPMENT PHASE		PRODUCTION PHASE
Reliability Task Area	Requirements Definition (30.1)	Design Support (30.2)	Development (30.3)	Qualification (30.4)	Production (30.5)
Key	• Life Cycle Profile Definition	• Establish Design Criteria	• Update Reliability Model & Production	• Reliability Qualification Test (MIL-STD-781)	• Reliability Acceptance Tests (MIL-STD-781)
Related Tasks	• Environmental Requirements Definition • Establish Field Service Reliability of Similar Systems & Equipment	• Conduct Design Analysis - Thermal Design - Failure Mode Effects and Criticality Analysis • Define Quantitative Reliability Requirements • Reliability Allocation • Prepare Reliability Prediction • Prototype Testing	• Update FMECA • Perform Reliability Development Testing (Test-Analyze-and-Fix)	• Environmental Qualification Test	• Environmental Acceptance Tests
Key Supportive Tasks	• System Effectiveness Analysis • Obtain Field Service Reliability and Environmental Data from similar systems and equipment	• Parts Qualification • Application and Derating Criteria • Determination of Qualification and Acceptance Test Conditions, procedures and accept/reject criteria	• Failure Recurrence Control Program • Trend Analysis • Documentation Review	• Failure Recurrence Control Program • Trend Analysis • Parts Qualification • Documentation and Change Review • Burn-in and Screening	• Failure Recurrence Control Program • Trend Analysis • Parts Qualification • Change Review • Stockpile Surveillance • Process Control • Burn-in and Screening

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40. RELIABILITY PROGRAM TASKS

40.1 Operational life profile definition. Each significant life cycle event should be identified in terms of functions to be performed, operating modes, ON/OFF cycling conditions, event durations, equipment locations, and equipment conditions (packaged, stored, mounted for use, operational, and so forth). The operational life cycle profile will include one or more mission profiles (individual tactical situations).

40.2 Environmental requirements definition. A description of the environmental levels and durations to be encountered during each life cycle event (including packaging, handling, storage, transportation, and operational events) should be recorded. The individual environmental exposures should then be combined to form the system environmental specification. Where applicable, separate environmental specifications should be prepared for each subsystem or unit to be subjected to reliability testing in accordance with this document.

40.3 Reliability requirements definitions. Quantitative reliability requirements should be developed for each phase of the life cycle to allow the system to meet the systems effectiveness requirements.

40.4 Reliability allocation. The system reliability requirements derived in 40.3 should be apportioned to the various subsystems and components, using appropriate mathematical techniques, to provide specific design requirements for each subsystem and component.

40.5 System effectiveness analysis. The basic requirements for the system should be defined based on user needs, and other tactical considerations such as threat analysis, target and weapon vulnerability, lethality, desired availability and dependability.

40.6 Design criteria definition. Specific design criteria should be defined prior to the actual design effort to provide guidance regarding features which must be incorporated into the design to assure meeting the design requirements. Typical design criteria include Parts Application and Derating Criteria, Preferred Parts Lists, Non-Standard Parts Control Requirements, Mechanical and Thermal Design Requirements, use of redundancy, and so forth. The design criteria should also assure that the reliability requirements, as derived from the requirement analysis and allocation studies, is properly treated by the design group.

40.7 Design analyses. Independent assessments of the design should be performed as the design matures to assure conformance to the design criteria, and to identify problem areas for design resolution. Typical tasks include: electrical, mechanical, and thermal stress analyses (calculated or measured to assure conformance to the derating criteria or to established safety margins); mechanical and electrical tolerance analysis (calculations to assure adequate production yields, interchangeability, and achievement of specified performance); environmental analysis (design analysis to assure that the design is capable of surviving in the intended use environment); Failure Modes, Effects, and Criticality Analysis (identification of single and multiple failure modes, and the incorporation of corrective action to improve the fault tolerant capabilities of the design); and Sneak Circuit Analysis (analysis of the system and its interfaces and ancillary equipment to identify and eliminate latent paths which cause undesired functions or inhibit desired functions).

40.8 Reliability model definition. Block diagrams and reliability math models of the system or equipment, depicting the functional interrelationships for satisfactory system performance, should be recorded and maintained current as the design matures.

40.9 Reliability prediction. A prediction should be made of the reliability of the design to provide confidence that the equipment or system will meet the reliability requirement. The prediction should be maintained current as the design matures.

40.13 Parts qualification. A program should be implemented to assure that all parts and materials used in the design have been qualified, including environmental, performance, reliability, and quality considerations, and that all vendors maintain adequate quality assurance programs.

40.14 Documentation and change review. Production versions of the design disclosure drawings and specifications should be reviewed to assure that reliability and quality assurance provisions are properly controlled. All changes should be reviewed prior to incorporation to assure that reliability will not be degraded.

40.15 Process control. Assembly procedures, manufacturing instructions, test procedures, inspection procedures, and process control procedures, and all changes thereto, should be reviewed for adequate reliability controls. Inspection results and test data should be monitored to detect new or potential problems.

40.16 Stockpile surveillance. Equipments that have been placed in inventory and deployed to the field should be continuously monitored for failure trends to provide feedback to production for refinement of the design production processes, acceptance test procedures and so forth.

40.10 Integrated test planning. In every new equipment procurement, an Integrated Test Plan should be generated early in the program to gain the greatest benefit from the various test phases, which should complement each other and reduce duplication. During the development phase, after engineering tests have been completed and prototype equipments have been built, the environmental qualification tests have to be carried out. The reliability growth testing, if required, may begin in parallel with environmental qualification but any design changes required to meet environmental requirements must be incorporated in the preproduction units being used for the reliability tests.

To gain the greatest benefit from the failures encountered during the testing program a closed-loop failure reporting analysis and corrective action system should be implemented at the beginning of the first formal test, usually one of the environmental qualification tests and it should remain effective through the production phase. The various types of testing to be covered in a full-scale development and production program are presented in the following paragraphs.

40.10.1 Reliability development testing. Sufficient testing should be conducted to provide confidence that the equipment reliability meets or exceeds the value of θ_0. This is a test, analyze and fix (TAAF) type test and normally consists of a sequence of testing, analyzing all failures, incorporating corrective action, and retesting, with the sequence repeated until assurance is obtained that the required reliability can be demonstrated during the reliability qualification test.

40.10.2 Environmental development testing. Sufficient testing should be conducted to provide confidence that the equipment will operate satisfactorily in the intended use environment. Testing should include exposure to both individual environments and combinations of environments. This normally consists of a sequence of testing, analyzing all failures, incorporating corrective action, and retesting with the sequence repeated until the required capability has been demonstrated.

40.10.3 Environmental qualification test. Environmental qualification tests should be conducted to demonstrate that the documentation package, the manufacturing procedures, and the reliability and quality programs provide hardware which will function properly under the specified environmental conditions.

40.10.4 Reliability qualification test (MIL-STD-781). Reliability qualification tests in accordance with MIL-STD-781 should be performed to provide a high degree of confidence that the hardware reliability meets or exceeds the requirements.

40.10.5 Reliability acceptance tests (MIL-STD-781). Reliability acceptance tests should be conducted either on a lot-by-lot sampling basis or on an all equipment testing basis utilizing an appropriate MIL-STD-781 test plan. Such tests will provide confidence that the hardware reliability will continue to meet requirements.

40.10.6 Burn-in and screening tests. Burn-in and screening tests should be developed and implemented at various levels of assembly, including the end item, to assure that equipment presented for qualification or acceptance testing is free of workmanship defects and other infant mortality problems.

40.11 Failure recurrence control program. A program for the collection of failure data, the analysis of the failures to identify the causes, and the development, incorporation, and evaluation of corrective actions to preclude failure recurrence should be implemented.

40.12 Trend analyses. Hardware performance data, reliability assessment data, and failure reports should be analyzed to identify and correct areas of specification incompatibility, undesirable trends in performance or reliability, and otherwise undetected problem areas.

APPENDIX B

RELIABILITY QUALIFICATION AND ACCEPTANCE TEST CONDITIONS

10. GENERAL

10.1 Scope. This appendix discusses the test conditions for reliability qualification and acceptance tests, including the analyses necessary to establish conditions appropriate to the particular system or equipment.

10.2 Purpose. The purpose of this appendix is to provide guidance to those responsible for the establishment of the conditions applicable to reliability qualification and acceptance tests as pertinent to the particular system or equipment under consideration.

20. APPLICABLE DOCUMENTS

MIL-E-5400	Electronic Equipment, Airborne, General Specification For
MIL-E-16400	Electronic, Interior Communication And Navigation Equipment, Naval Ship And Shore: General Specification For
MIL-STD-1670(AS)	Environmental Criteria And Guidelines For Air Launched Weapons
MIL-STD-810	Environmental Test Methods
MIL-STD-210	Climatic Extremes For Military Equipment

30. DEFINITIONS Not applicable.

40. MISSION/ENVIRONMENTAL PROFILES AND TEST CONDITIONS

40.1 Mission/environmental profiles. The mission/environmental profiles should be used to determine the equipment's environmental specifications. The mission profiles to be included are derived from the operational life profile as defined by the stated operational requirements for the equipment/system being procured. If such information is not provided in the original contractual documentation, provision should be made by the procuring activity, in conjunction with the contractor to cooperatively derive the mission/environmental profiles and the equipment environmental specifications by investigation of historical data on similar equipment applications and mounting platform(s). Each significant life-cycle event must be considered: transporting, handling, installation and checkout, and each tactical mission (if more than one defined) to which it will be applied, including platform category and operational situation.

40.2 Derivation of test conditions/levels. Test conditions/levels are derived from the equipment's environmental specifications and the life-mission profiles.

40.2.1 Reliability qualification and acceptance test conditions. The statistical reliability qualification and acceptance tests are carried out under the combined environmental conditions of electrical input, temperature, vibration and generally humidity. The test levels for these various conditions are to be derived from the mission/environmental profiles for that particular equipment in its field service application. When equipment is designed for one application with a single mission or one type of repetitive mission, the test cycle profile is essentially the mission/environmental profile. The test conditions are made to simulate the actual stress levels over the durations present during the mission. If the equipment is applicable to several types of missions and environmental conditions, the test cycle profile should be a composite of the various missions with the test levels and duration prorated according to the percentage of each mission type expected during the equipment's life cycle. Of course, in order to derive test conditions and levels as indicated above, the actual environments (especially temperature and vibration) must be measured at the location where the equipment is to be mounted during an actual mission operation. Where such data, or similar data, are not available, the conditions and levels presented in Section 50 of this appendix may be used as guidelines.

50. COMBINED ENVIRONMENTAL TEST CONDITIONS

The environmental test conditions and stress levels are specified for each category of equipment classification:

Category 1 Fixed ground equipment (see 50.1)
Category 2 Mobile ground vehicle equipment (see 50.2)
Category 3 Shipboard equipment (see (50.3)
A. Sheltered
B. Unsheltered
Category 4 Equipment for jet aircraft (see 50.4)
Category 5 Turbo-prop aircraft and helicopter equipment (see 50.5)
Category 6 Air-launched weapons and assembled external stores (see 50.6)

50.1 Combined environments for fixed ground equipment.

50.1.1 General. Equipment designed for fixed ground installation is generally located in a controlled environment within a building and therefore does not require cyclic environmental criteria for testing. However, such equipment does have to be transported to its final installation site; therefore, a nominal vibration test is to be applied, with power off, before each reliability test. Contractually specific operating conditions and environments shall be used during the reliability qualification and acceptance tests. If none are specified, the environmental criteria presented in the following paragraphs may be used as guidelines in preparing the test plan and procedures.

50.1.2 Electronic stress. The equipment shall be operated at nominal design input power voltage for 50 percent of the time, and at minimum and maximum input voltages for 25 percent of the time, respectively. Minimum range, if not specified, shall be nominal +5 percent to nominal -2 percent. Length of operating cycle will depend on the operational use of the equipment - 4 hour shift, 8 hour shift, 16 hours per day, or round-the-clock continuous operation with periodic shutdowns for routine maintenance.

50.1.3 Vibration stress. None required during operation. If the equipment is not packaged specifically for transportation to its installation site, a nominal vibration stress shall be applied as follows: single frequency sine-wave vibration at 2.2 g pk between 20 and 60 Hz for 20 minutes for each equipment before starting the reliability test. If equipment has a specified shipping configuration, it shall be qualified for adequate shipping protection by packing equipment in its specified configuration, and testing in accordance with the shipping vibration and shock expected, before starting the reliability test.

50.1.4 Thermal stress. The equipment will be operated at its specified ambient temperature condition. If not specified, use thermal condition A, B, or C as appropriate.

A - Installed in an occupied building with air conditioning/heating automatically controlled, use 20°C as operating ambient
B - Use 40°C if not air conditioned but where summer heat could approach such a temperature
C - If an unoccupied, non-air-conditioned enclosure and in semi-tropical or tropical location, do one half of testing at 60°C, one quarter at 40°C, and one quarter at 20°C

50.1.5 Humidity. None required unless specified in contract.

50.2 Combined environments for mobile ground equipment, vehicle mounted.

50.2.1 General. The specific application for the equipment shall be considered when specifying the combined environments for reliability tests, for example, the type of vehicle and the geographical region where it will be deployed. MIL-STD-210 shall be used to determine climatic extremes for the geographical area where the equipment and vehicle will be used. MIL-STD-810 can provide guidance for the vibration requirements. Mounting platforms include tracked and wheeled vehicles. Operating time on moving vehicle versus operating time while stationary must also be considered in developing a cyclic test similar to the one shown in FIGURE B-1.

50.2.2 Electrical stress. The equipment shall be operated at nominal design input power voltage for 50 percent of the time, and at minimum and maximum input voltages for 25 percent of the time, respectively. Minimum range, if not specified elsewhere, shall be ±10 percent of nominal. Length of operational cycle shall be based on mission requirements and design specifications.

If designed for continuous operation for an eight-hour shift, the operating cycle shall be eight hours with complete shut-down before the next operation, long enough for equipment to stabilize at the specified ambient temperature.

50.2.3 Vibration stress. Swept sine-wave vibration shall be applied over the frequency range of 5 to 500 Hz for 15 minutes per hour of operation as follows: 1.0 inch (25.4 mm) double amplitude (DA), 5 to 6.3 Hz, 2g from 6.3 to 500 Hz unless specific requirements are given elsewhere. For example, if the equipment is operated the majority of the time with the vehicle stationary, the vibration shall be applied for only a specific portion of the operating cycle. MIL-STD-810, Test Method 514.2, Procedure VIII may be used as a guideline for vibration requirements.

50.2.4 Thermal stress. The equipment shall be operated at its specific ambient temperature conditions from minimum to maximum as indicated in FIGURE B-1. If no ambient temperatures are specified, the following shall be used:

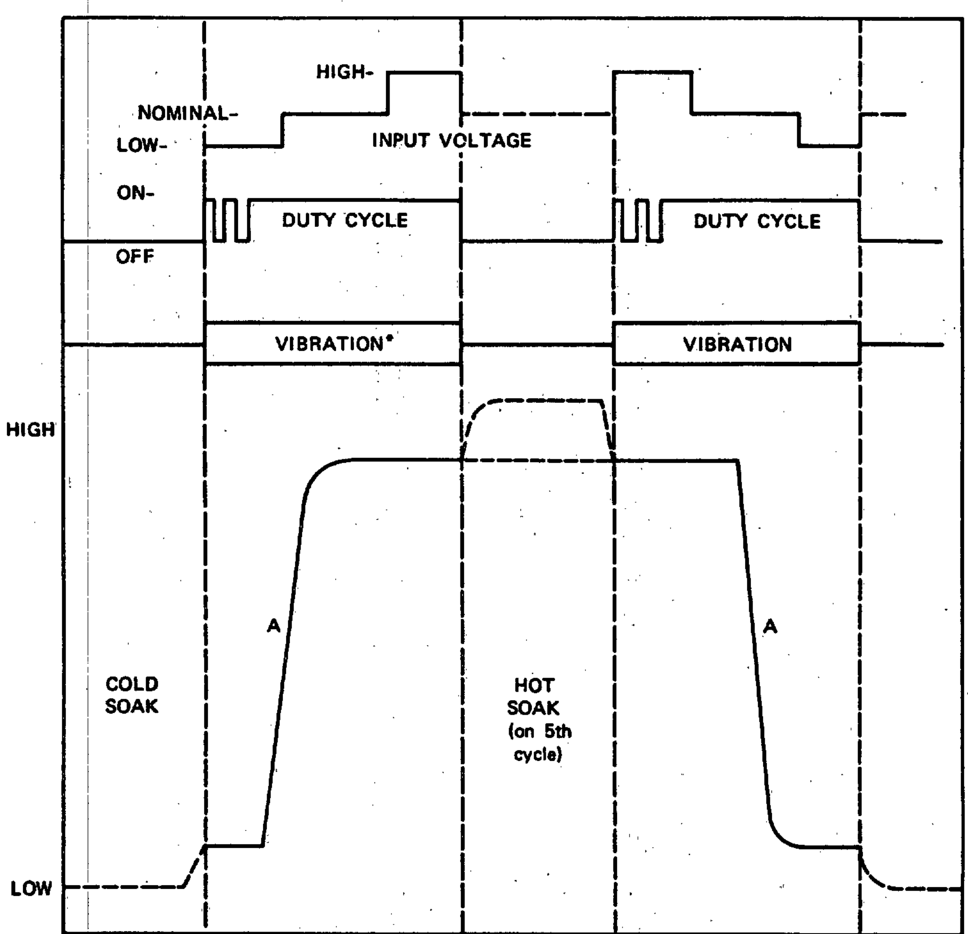
Cold soak temperature:	-54°C (start of normal cycle)
Hot soak temperature:	+85°C (every 5th cycle)
Operating temperature range:	-40°C to +55°C

50.2.5 Moisture. Moisture levels sufficient to cause visible condensation and frosting shall be used, when such conditions can be expected in the field service environment of the equipment under test. Humidity need not be held constant during the test cycle, and high levels may be accomplished by moisture injection at appropriate times in the test cycle.

50.3 Combined environments for shipboard equipment.

50.3.1 General. Shipboard equipment installed within enclosed operating areas of a ship are not exposed to the extreme conditions of the unsheltered deck or super-structure and mast areas. Therefore, the function of the equipment and its installed location determine the environmental stresses. The following paragraphs shall be used if the environmental conditions are not specified in the contractual documents nor in the equipment specifications. Note different stress levels in thermal area for sheltered and unsheltered installations.

50.3.2 Electrical stress. During the operating cycle, input voltage shall be adjusted to various levels as shown in FIGURE B-2 based on specified input voltage ranges for the equipment. If not otherwise specified, the input voltage range shall be ±7 percent of nominal design voltage. After reference measurements are taken at nominal voltage at room temperature, minimum voltage shall be applied for the initial period of the operating cycle and maximum voltage during the highest ambient temperature and for the balance of the cycle, nominal voltage shall be applied.



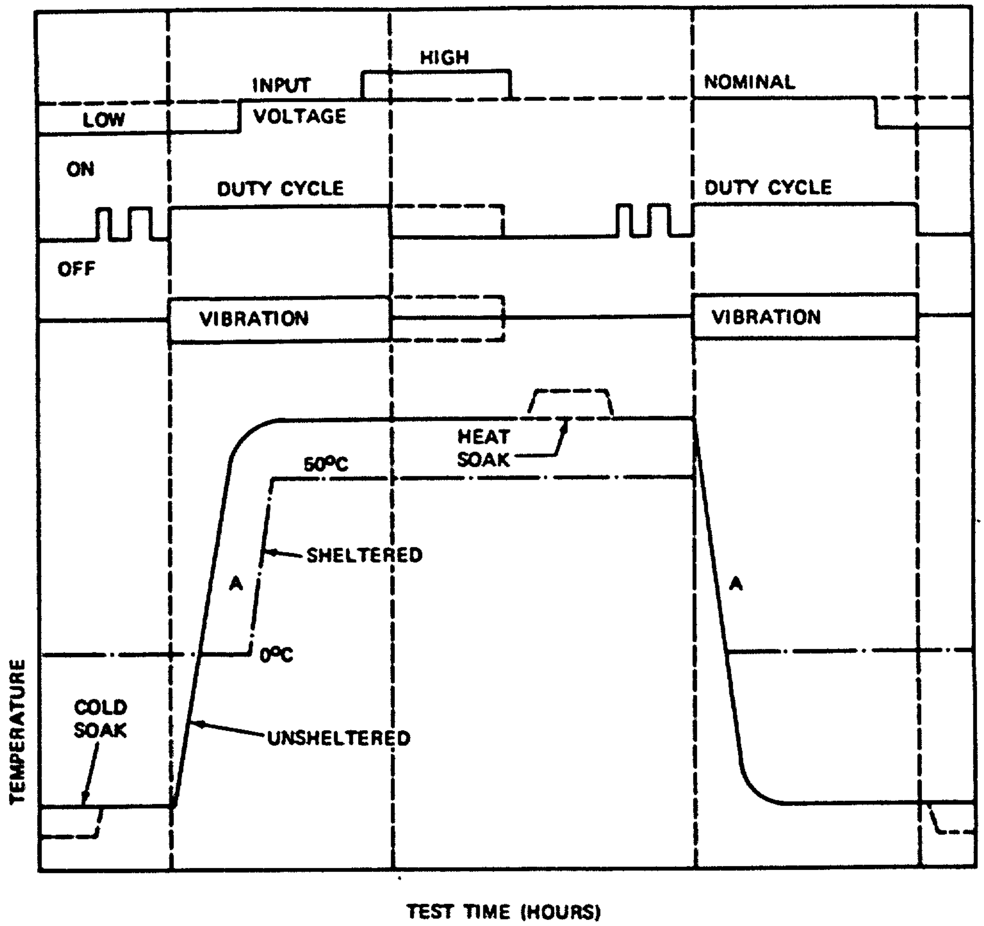
A - Rate of chamber temperature change shall average 5°C/minute unless otherwise specified

------ non-operating

——— operating

*15 minutes per hour of operation.

FIGURE B-1. Typical environmental cycle mobile ground equipment.



A. Rate of chamber temperature change shall average not less than 5°C/minute but not greater than 10°C/minute.

FIGURE B-2. Test cycle (typical shipboard).

50.3.3 Vibration stress (continuous). The vibration stress to be applied shall be based on the vibrations that may exist at the mounting platform. If these are unknown, the stresses for either sheltered or unsheltered installations shall be:

Amplitude:	.020 inch (DA) ±.004 inch (DA) (.508 mm (DA) ±.102 mm (DA))
Frequency range:	4 Hz - 33 Hz - 4 Hz
Sweep time:	10 minutes ±2 minutes (up and down)

The test shall be run in a single axis to be specified by the contractor in the test plan and approved by the procuring agency.

50.3.4 Thermal stress. The temperature limits, minimum and maximum, shall be based on the mission requirements and equipment specifications. If these are not thus specified, the equipment shall be subjected to the thermal conditions listed in TABLE B-I, depending on installation in a sheltered or unsheltered mounting platform.

TABLE B-I. Thermal conditions.

Range	Environmental Condition	Operating °C	Nonoperating °C
1	Exposed-unsheltered	-54 to +65	-62 to +71
2	Exposed-unsheltered (ship)	-28 to +65	-62 to +71
3	Sheltered non-controlled environment (shore)	-40 to +50	-62 to +71
4	Sheltered controlled environment (ship or shore)	0 to 50	-62 to +71

The temperature cycle shall be similar to FIGURE B-2 unless otherwise specified in the contractor equipment specifications. In developing the temperature cycling requirements, the particular stress levels, rates and frequencies of changes, and equipment ON-OFF and duty cycles shall be as specified in the equipment specification. These particulars shall also be described in the test plan and test procedure.

50.3.5 Moisture. Moisture levels sufficient to cause visible condensation, frosting, and freezing should be specified when such conditions can be expected in the field service environment of the equipment under test. Humidity need not be held constant during the test cycle and may be accomplished by moisture injection at appropriate times in the test cycle.

Unsheltered shipboard equipment shall be subjected to high humidity (precipitation) during each cycle so that visible condensation or frosting takes place. Sheltered equipment in a controlled environment shall be subject to condensation of moisture only if such conditions can occur during actual operational or standby conditions.

50.4 Combined environments for jet aircraft equipment.

50.4.1 General. For the purpose of this test, a generalized test cycle shall be used. During this cycle the thermal, vibration, humidity and input voltage imposed on the test item shall be simultaneously varied. One complete test cycle is shown in FIGURE B-3. This cycle consists of two missions. One mission starts from a cold environment and proceeds to a hot environment. The second starts in a hot environment and returns to a cold environment. The specific test conditions for each Phase A through J will be determined by the type of aircraft into which the equipment is to be installed; its location within the aircraft; the aircraft mission profiles; the equipment class designation (in accordance with MIL-E-5400); type of cooling for compartment in which the equipment is located (air conditioned or ram air cooled); and type of equipment cooling (ambient or supplemental air).

50.4.2 Mission profiles. An individual aircraft type is designed to operate within a specific flight envelope and to fly specifically determined mission profiles. For production aircraft and for aircraft under prototype development, these design flight envelopes and designated mission profiles should be utilized when formulating the environmental profiles for test. When design flight envelopes and specifically designated flight mission profiles are not available, the generalized mission profiles listed in TABLES B-II, B-III, and B-IV of this appendix shall be used as a basis for development of environmental profiles for test. A typical fighter aircraft mission time of one hour and forty minutes shall be used when more specific information is lacking. Six and one half hours shall be used for a typical transport or cargo aircraft mission. With mission profile information available, the following paragraphs shall be used to establish environmental conditions for test.

50.4.3 Environmental test cycle formulation. The test environments are comprised of combined thermal, vibration, humidity with input voltage cycling stresses. The test levels to be used for each of these environments shall vary according to the aircraft mission profile established for test. Aircraft mission profiles shall be analyzed by individual flight phases such as take-off, climb, mission objective (cruise, combat, acceleration) descent and landing. In addition to these flight phases, the ground park and ground operation phases shall be analyzed for environmental conditions.

50.4.3.1 Electrical stress. Input voltage shall be maintained at 110 percent of nominal for the first test cycle, at the nominal value for the second test cycle, and at 90 percent for the third test cycle. This cycling procedure is to be repeated continuously throughout the test. However, this sequence may be interrupted for repetition of input voltage conditions related to a suspected failure.

The equipment to be turned ON and OFF at least twice before continuous power is applied to determine start up ability at the extremes of the thermal cycle.

50.4.3.2 Vibration stress. Random vibration shall be applied to the equipment item designated for jet aircraft installation in accordance with 50.4.3.2.1. The random vibration test level for each phase of the test cycle shall be determined using FIGURE B-4 and TABLE B-V. (FIGURE B-5 shows the relationship between Mach numbers, altitude, and q). When an equipment is to be installed in more than one location in the aircraft or used in more than one aircraft, the highest random vibration level computed for each test phase shall be used.

50.4.3.2.1 Performance test. The individual equipment test item or items shall be subjected to random vibration excitation in one axis. The power spectral density tolerances of applied vibration shall be according to the random vibration test paragraph of MIL-STD-810, Method 514.2.

The test item shall be attached to the vibration exciter according to the mounting techniques paragraph of MIL-STD-810, Method 514.2. Equipment hard-mounted in service is to be hard-mounted to the test fixture. Equipment soft-mounted in service shall use service isolators when mounted on the test fixture. If service isolators cannot be made available during the qualification test, isolators shall be provided with characteristics such that the isolator/equipment resonant frequencies shall be between 20 Hz and 45 Hz with resonant amplication ratio between 3 and 5. The acceleration power spectral density (g^2/Hz) of applied vibration, as measured on the test fixture at mounting points of the test item, shall be according to TABLE B-V and FIGURE B-4. The duration of each phase of the tests shall be determined from the mission analysis.

TYPICAL MISSION PROFILES

TABLE B-II. Air superiority fighter.

Flight Mode	Test Phase*	Percent Time	Altitude (1000 ft)	Mach Number	q (psf)
Ground Runup (no AB) (with AB)	A,F	4 1	0 to 0.5	0	-
Takeoff	B,G	5	0.5 to 1	0 to 0.4	-
Climb (to 40,000 ft)	B,G	8	to 40	0.6	245
Cruise (500 ft) (20,000 ft) (40,000 ft)	C,H	6 5 40	.5 20 40	0.8 0.9 0.9	900 550 225
Acceleration	C,H	4	40 to 50	1.7	620
Combat (500 ft) (5000 ft) (10,000-40,000 ft) (50,000 ft)	C,H	1 1 2 3	.5 5 10 to 40 50	0.85 0.9 2.0 2.5	900 1000 1800 1180
Descent	D,I	8	40 to 3	0.8	445
Loiter	D,I	8	3	0.4	200
Landing	D,I	5	3 to 0.5		

*See FIGURE B-3.

TABLE B-III. Interdiction fighter.

Flight Mode	Test Phase*	Percent Time	Altitude (1000 ft)	Mach Number	q (psf)
Ground Runup (no AB) (with AB)	A,F	4 1	0.5 0.5	0 0	- -
Takeoff	B,G	4	0.5 to 1	to 0.4	-
Climb (to 35,000 ft)	B,G	5	to 35	.6	245
Cruise (500 ft)	C,H	27 32	.5 35	0.8 0.9	900 280
Accleration	C,H	3	35 to 50	1.7	620
Combat (500 ft) (10,000-35,000 ft) (50,000 ft)	C,H	2 1 4	.5 10 to 35 50	0.85 2.0 2.5	900 1800 1180
Descent	D,I	6	40 to 3	0.8	445
Loiter	D,I	7	3	0.4	200
Landing	D,I	4	3 to 0.5		-

*See FIGURE B-3.

TABLE B-IV.

Typical mission profile transport/cargo aircraft.

Flight Mode	Test** Phase	Time Percent	Airspeed Knots*	q (psf)
Ground Runup	A,F	5	-	-
Takeoff/climb	B,G	5	To 260	200
Cruise High Altitude 36K	C,H	70	240	210
Medium Altitude 22K		5	250	225
Low Altitude 1K		10	350	400
Descent/land	D,I	5	140	100

* Knots Equivalent Airspeed
** See FIGURE B-1

Phase	Test Phase Definition	Duration	Operating/Non-Operating
A	Ground Operation - Cold Day	30 Minutes	Operating
B	Takeoff/Climb to Altitude	Defined by aircraft mission profile	Operating
C	Mission Objective	Defined by aircraft mission profile	Operating
D	Idle Let Down & Landing	Defined by aircraft mission profile	Operating
E	Ground - Hot Day	*	Non-Operating
F	Ground Operation - Hot Day	30 Minutes	Operation
G	Takeoff/Climb to Altitude	Defined by aircraft mission profile	Operating
H	Mission Objective.	Defined by aircraft mission profile	Operating
I	Descent	Defined by aircraft mission profile	Operating
J	Ground - Cold Day	*	Non-Operating

* See paragraph 50.4.3.3

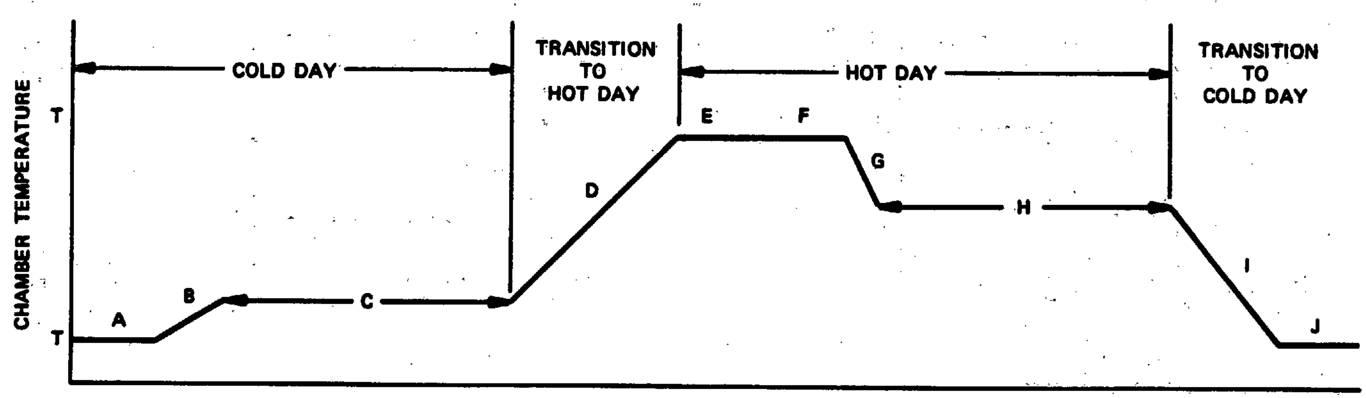
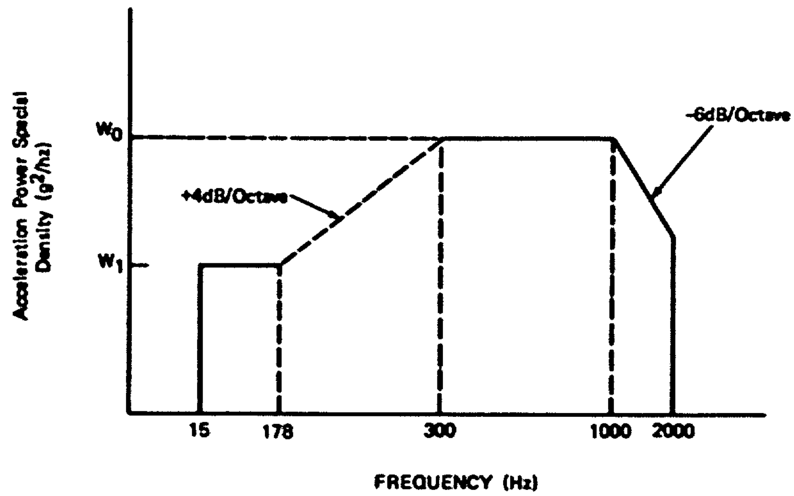


FIGURE B-3. Typical mission test cycle profile.

FUSELAGE



WING & FIN TIP

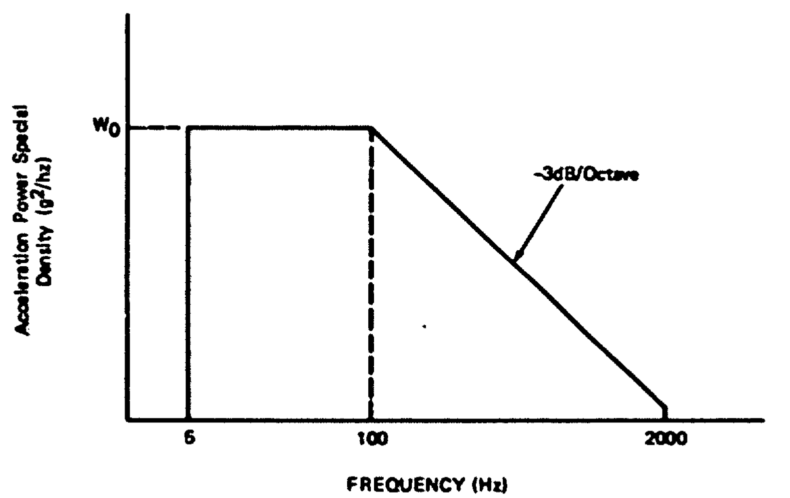


FIGURE B-4. Jet aircraft-random vibration test envelope.

TABLE B-V. Jet aircraft - random vibration test.

Aerodynamic Induced Vibration

$W_0 = K(q)^2$ q = Dynamic Pressure (when q > 1200 psf use 1200) (See 50.4.3.2.2a)

$W_1 = W_0$ -3 dB

(FIGURE B-2 for Spectrum Shape)

K	Equipment location
$.67 \times 10^{-8}$	Equipment attached to structure adjacent to external surfaces that are smooth, free from discontinuities.
$.34 \times 10^{-8}$	Cockpit equipment and equipment in compartments and on shelves adjacent to external surfaces that are smooth, free from discontinuities.
3.5×10^{-8}	Equipment attached to structure adjacent to or immediatley aft of surfaces having discontinuities (that is, cavities, chins, blade antennas, and so forth)
1.75×10^{-8}	Equipment in compartments adjacent to or immediately aft of surfaces having discontinuities (that is, cavities, chins, speed brakes, and so forth)

SPECIAL CASE CONDITIONS

Fighter Bomber

Condition equipment location	W_0
Take off/attached to or in compartments adjacent to structure directly exposed to engine exhaust Aft of engine exhaust plane (1 minute)	.7
Cruise/(same as above)	.175
Take off/in engine compartment or adjacent to engine Forward of engine exhaust plane (1 minute)	.1
Cruise/(same as above)	.025
Take off, landing, maneuvers/wing and fin tips* decelleration (speed brake) (1 minute)	.1
High q (> 1000 psf)/wing & fin tips*	.02
Cruise/wing & fin tips*	.01
Take off/all other locations (1 minute)	.002

Cargo/Transport

Condition/equipment location	W_0
Take off/fuselage mounted	.01
Take off/internal	.005
Take off/wing-Aft of engine exhaust**	.05
All/wing tip and fin tip***	.01

* Use wing and fin tip spectrum - FIGURE B-4
** Excludes Upper Surface Blown (USB) and Externally Blown Flap (EBF)
*** Take off, landing, plus 10 percent of cruise time

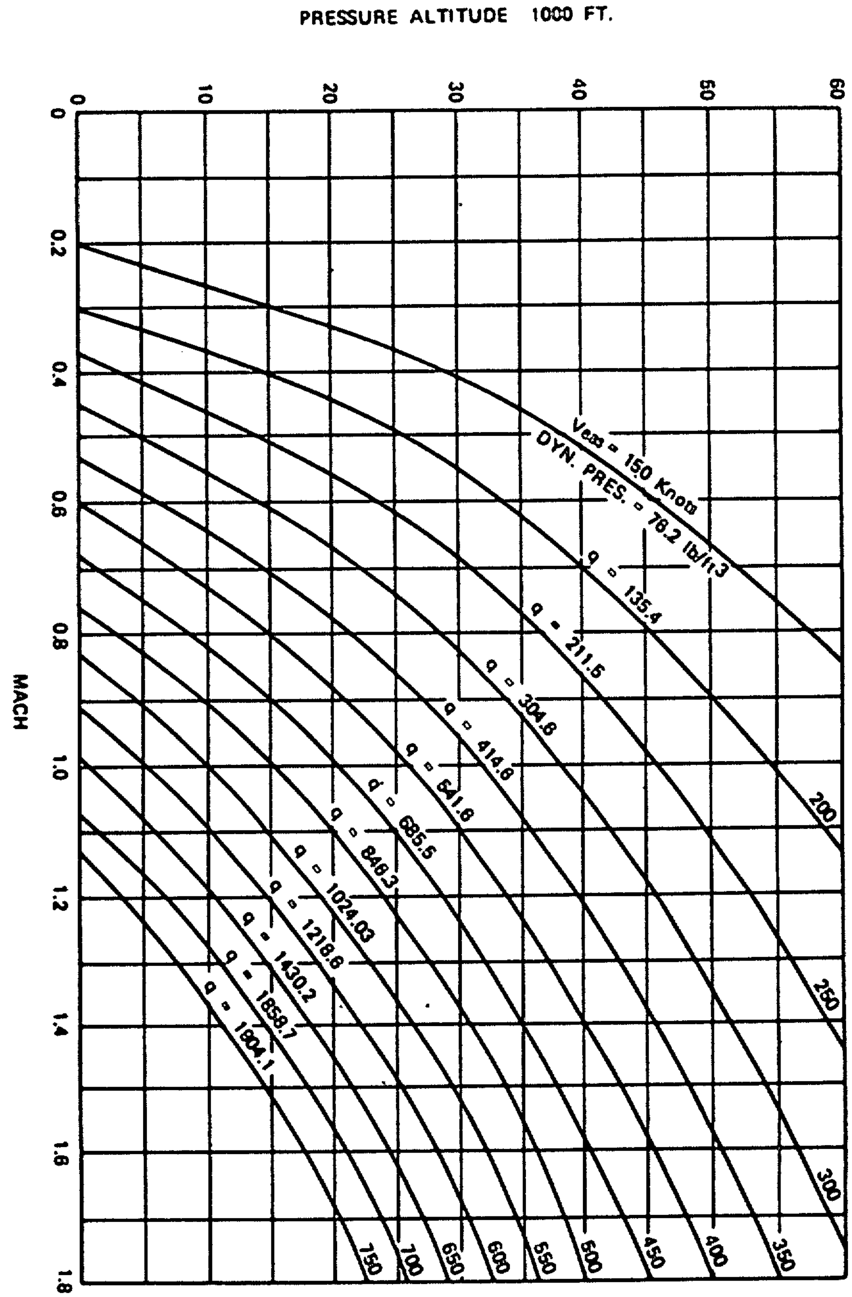


FIGURE B-5. Dynamic pressure (q) as function of mach number and altitude.

50.4.3.2.2 General notes.

a. Determination of mission profile vibration levels. The vibration level for each phase of the profile will be determined from TABLE B- V. A maximum of four W_o's will be determined by: (1) take off; (2) q_{max}; (3) q_{min}; and (4) q_{avg}. Where q_{max} is the maximum aerodynamic pressure encountered during the mission, usually at low altitude, high speed dash: q_{min} is the aerodynamic pressure associated with the flight phase that will generate a W_o above .001 g^2/Hz, normally a cruise condition. The fourth vibration level shall be determined by combining the vibration levels calculated for each of the other phases (climb, dive, combat, and so forth) having levels above the minimum (see c. below). An average q shall be used for each flight phase, that is, for a phase such as dive, the arithmetical average of the q at the start of the dive plus that at the termination of the dive shall be utilized ($q_{start} + q_{term})/2 = q_{avg}$. A W_o shall be calculated for each phase and flight phases with W_o's above the minimum shall be time weighted averaged to determine the fourth vibration level
b. Cargo aircraft. Unless unusual mission profiles are determined, take off and cruise profiles (vibration levels) will be the only required vibration levels
c. Minimum W_o test level. The minimum W_o test level shall be .001 g^2/Hz. If the calculated test level is less than .001 g^2/Hz, vibration test is not required during this portion of mission profile
d. Option. Maximum W_o determined may be used throughout test
e. Gunfire environment. Not considered in this test. Should be considered in environmental qualification test, if applicable (MIL-STD-810)
f. Composite vibration profile. Turboprop and jet aircraft usage; when equipments are to be installed in both turboprop and jet aircraft, a composite random spectrum shall be generated (see FIGURE B-6 for example, composite spectrum)
g. Wing and fin tip, fuselage equipments. When equipment is to be installed in both locations, a composite vibration profile shall be utilized where appropriate

50.4.3.3 Thermal stresses. The thermal stresses for supplementary cooled equipments shall be determined for each test phase in accordance with 50.4.3.3.1. All other equipments will use 50.4.3.3.2. The duration of test cycle Phases E and J shall be long enough to reach stabilization of temperature in accordance with the stabilization of test equipment paragraph of MIL-STD-810.

50.4.3.3.1 Supplementally cooled equipments. The flowrate, temperature, and dewpoint temperature of the supplemental air shall be in accordance with the equipment specification values during all phases, except Phases E and J. During test Phases E and J the supplemental airflow shall be zero. The thermal environment external to the test item shall be in accordance with 50.4.3.3.2. During chamber air heat up, the mass flow of supplemental air shall be minimum specified and held until chamber air cool down. During chamber air cool down, the mass flow of supplemental air shall be maximum specified and held until chamber air heat up.

50.4.3.3.2 Other equipments. The thermal stresses to be used in each test phase shall be in accordance with FIGURE B-3, TABLE B-VI, and applicable known mission profile (use TABLES B-II, B-III, or B-IV if a mission profile is not available). An example of construction of a thermal stress profile is presented in Section 50.4.4.

50.4.3.4 Humidity stress. Humidity should be specified to simulate the warm, moist atmospheric conditions especially prevalent in tropic climates. Moisture can be induced directly into equipment during flight in a humid atmosphere. Installed equipment is also subject to condensation, freezing and frosting as a result of climatic temperature-humidity conditions.

50.4.3.4.1 Supplementally cooled equipment. The chamber air humidity shall be in accordance with 50.4.3.3.2. The supplemental cooling air may be dried so that its dew point $3^{\circ}C\ ^{+0^{\circ}C}_{-10^{\circ}C}$ below the lower of the supplemental air or chamber air temperatures.

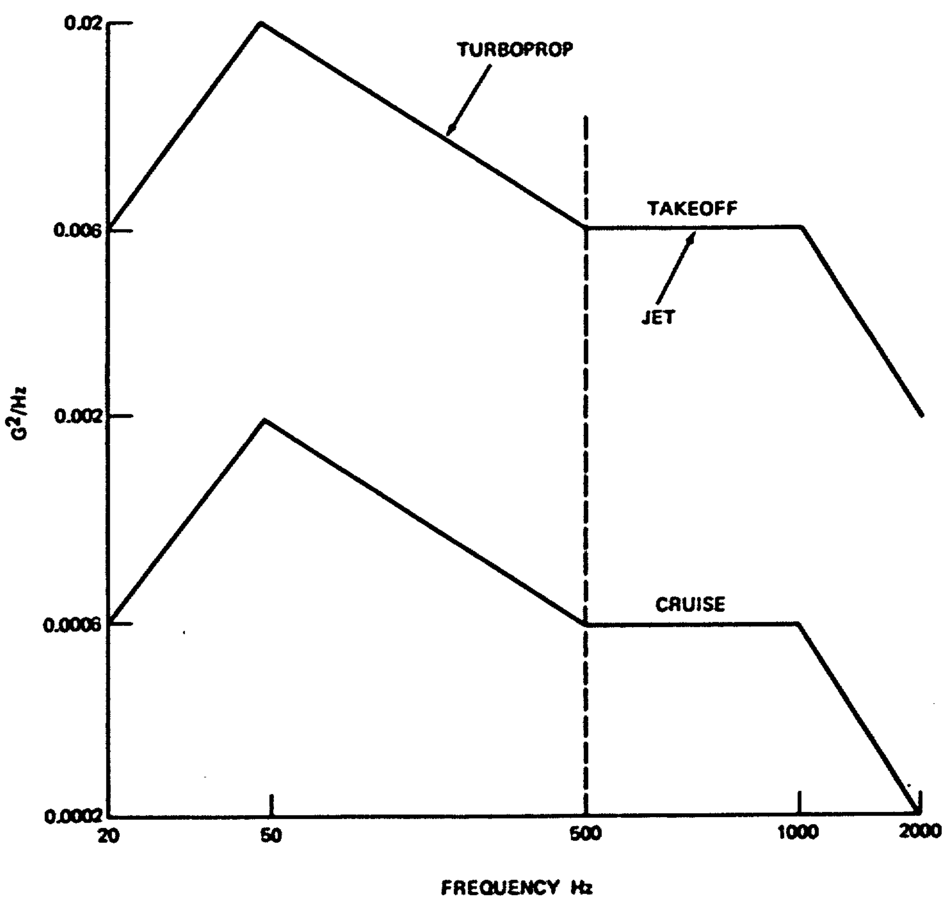


FIGURE B-6. Example turboprop and jet aircraft composite test spectra for equipment mounted within the fuselage.

50.4.3.4.2 Chamber air humidity. Humidity shall be injected into the test chamber from a steam source or other humidity source and controlled by a dewpoint controller or other humidity measuring instrumentation. A humidity dewpoint temperature of 31°C or greater shall be attained during the initial portion of Phase E of FIGURE B-1 of this appendix. The 31°C or greater dewpoint shall be maintained and controlled until the end of Phase F. No further injection of moisture is required for the other profile phases and humidity shall be uncontrolled. The humidity shall be maintained and controlled at 31°C or greater for each subsequent test cycle, Phase E and F. Drying of chamber air shall not be accomplished at any time during a test cycle.

50.4.4 Example construction of environmental profile. This example illustrates the use of aforementioned information in the construction of a mission test cycle profile for an assumed aircraft and equipment. The example information is as follows.

a. Equipment Class 2 in accordance with MIL-E-5400
b. Equipment installed in air-conditioned compartment
c. Equipment is ambient cooled (no supplemental cooling)
d. Equipment is attached to structure adjacent to external surfaces that are smooth, free from discontinuities
e. Mission diagram in accordance with FIGURE B-7. Aircraft climbs to 30,000 feet in seven minutes and is vectored to target in 23 minutes at Mach 1.0, and then makes a high performance dive in two minutes to intercept at 10,000 feet. After the intercept, aircraft flies at high performance speed at 10,000 feet for five minutes, then climbs to 40,000 feet in 13 minutes, and cruises to base in 35 minutes at Mach 0.6. Idle descent landing time is 15 minutes.

The steps for determining the temperature for each phase are shown in TABLE B-XII. The resulting profile is shown in FIGURE B-8. The temperature rate of change for each temperature step is equal to the difference in temperatures at the end and start of each step divided by the time to achieve that step (time to climb, dive, idle descent). The temperature rates of change for each phase of this mission example is shown in TABLE B-XIII.

The vibration conditions calculated for each flight phase are shown in TABLE B-XIV . TABLE B-XV shows the final vibration test conditions.

Humidity should be raised to 31°C dewpoint or greater at the beginning of Phase E. The 31°C or greater dewpoint measurement should be maintained until the completion of Phase F, Ground Operation Hot Day. For the remaining phases of the test profile, the humidity will be uncontrolled with no additional moisture injected. For repeated profile cycles, the dewpoint shall be checked as above for Phase E. and F.

Electrical stress shall be in accordance with 50.4.3.1.

50.5 Combined environments for turboprop aircraft and helicopter equipment.

50.5.1 General. The environmental test levels described herein are analogous to those occurring in aircraft with turbopropeller engines and in helicopters and are applicable to equipment mounted within the fuselage. The indicated stress values presented in the following paragraphs shall be used only if actual stress levels are not specified in contractual documents and mission profiles are not provided. Gunfire induced vibration should be considered when the equipment is mounted in an attack helicopter, and MIL-STD-810, Method 519.2 should be consulted.

50.5.2 Electrical stress. Input voltage shall be maintained at 110 percent of nominal for the first thermal cycle, at the nominal value for the second thermal cycle, and at 90 percent for the third thermal cycle. This cycling procedure is to be repeated continuously throughout the reliability development test. However, this sequence may be interrupted for repetition of input voltage conditions related to a suspected failure.

The equipment to be turned ON and OFF at least twice before continuous power is applied to determine start up ability at the extremes of the thermal cycle.

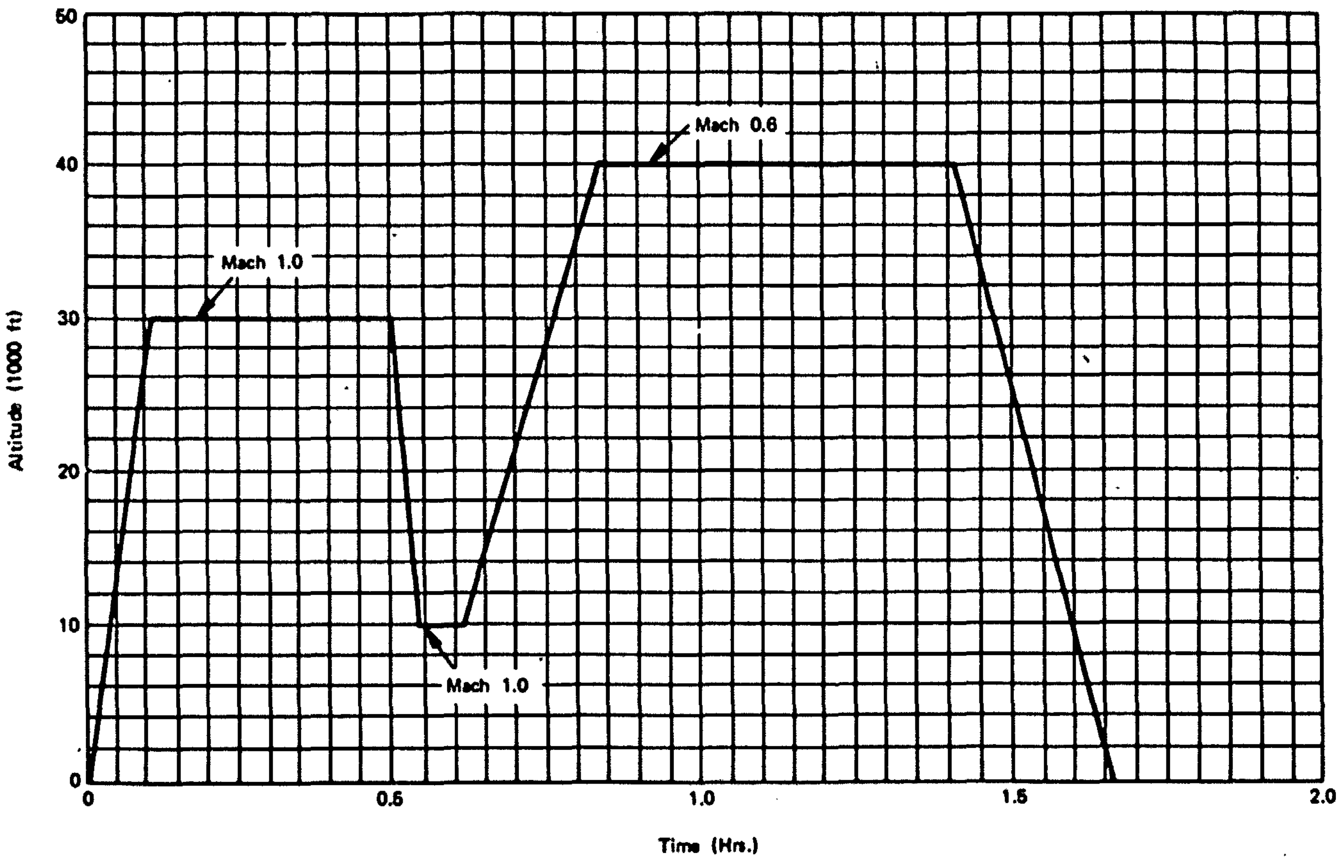


FIGURE B-7. Mission profiles for example.

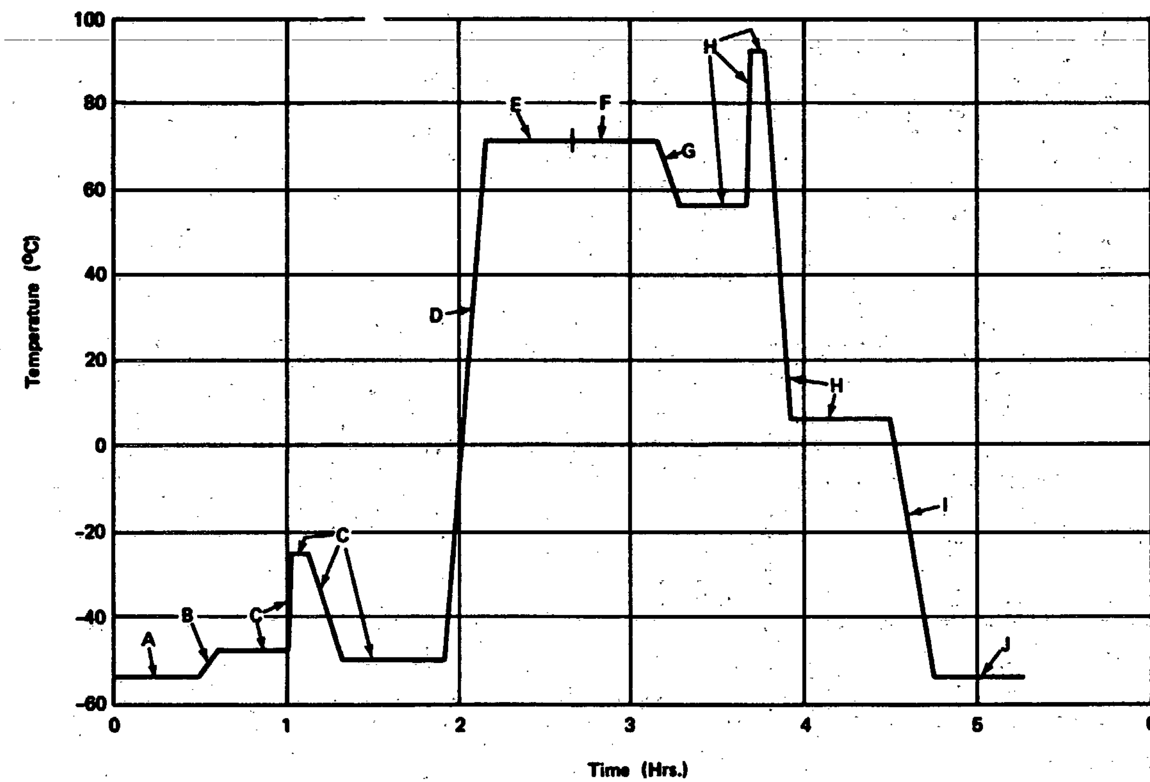


FIGURE B-8. Thermal profile for examples.

TABLE B-VI. Thermal stress profile base.

Phase	Test phase definition	Duration	Chamber limits		
			Class I 2/	Class II 2/	Ram cooled 2/
A	Ground Operation Cold Day	30 minutes	-54°C	-54°C	-54°C
B	Take-Off Climb to Altitude	1	TABLE B-VII	TABLE B-VII	TABLE B-XI
C	Mission Objective	1	TABLE B-VII	TABLE B-VII	TABLE B-XI
D	Idle Let Down & Landing	1	TABLE B-VIII	TABLE B-VIX	TABLE B- X
E	Ground Non-Operation Hot Day	3	71°C	71°C	71°C
F	Ground Operation Hot Day	30 minutes	71°C	71°C	71°C
G	Take-Off & Climb to Altitude	1	TABLE B-VIII	TABLE B-VIX	TABLE B- X
H	Mission Objective	1	TABLE B-VIII	TABLE B-VIX	TABLE B- X
I	Descent & Landing	1	TABLE B-VII	TABLE B-VII	TABLE B-XI
J	Ground Non-Operation Cold Day	3	-54°C	-54°C	-54°C

1/ Duration based on aircraft mission profile.

2/ Temperature rate of change shall be that resulting from the mission thermal profile construction except that the minimum used shall be 5°C/minute.

3/ When stabilization is reached determines the duration of these phases, in accordance with the paragraph on stabilization of nonoperating test temperature in the general requirements section of MIL-STD-810.

TABLE B-VII. Cold day ambient temperature (°C) for Class I and II equipment in air-conditioned compartments.

Altitude (K feet)	Temperature
0	-54
2	-26
10	-26
20	-48
30	-50
40	-50
50-70	-50

TABLE B-VIII. Hot day temperatures (°C) for Class I equipment in air-conditioned compartments.

Altitude (K feet)	Temperature (°C)
0	55
10	53
20	40
30	40
40	30
50	20

TABLE B-IX. Hot day ambient temperature (°C) for Class II equipment in air-conditioned compartments.

Altitude (K feet) \ Mach Number	≤0.6	0.8	1.0	High Performance (1.0)*
0	71	71	71	95
10	56	68	68	93
20	40	55	63	88
30	15	36	56	80
40	5	10	46	70
50	5	10	35	60
60	5	10	24	49
70	5	10	11	35

* Ambient cooled equipment must be turned off for 15 minutes after 30 minutes of operation at these temperatures to comply to the Intermittent Operation of MIL-E-5400.

TABLE B-X. Hot day ambient temperatures (°C) for equipment in RAM cooled compartments.

Altitude (K feet) \ Mach number	0.4	0.6	0.8	1.0
0	48	60	75	95*
10	27	38	52	71
20	6	16	29	46
30	-15	- 6	7	23
40	-36	-30	-16	- 1
50	-30	-19	- 7	8
60	-31	-23	-11	4
70	-30	-22	-10	5

* Ambient cooled Class 2 equipment must be turned off for 15 minutes after 30 minutes of operation at this temperature to comply with the Intermittent Operation requirement of MIL-E-5400.

TABLE B-XI. Cold day ambient temperatures (°C) for equipment in RAM cooled compartments.

Altitude (K feet) \ Mach number	0.4	0.6	0.8	1.0
0	-44	-37	-15	-11
10	-18	-10	2	19
20	-36	-28	-16	- 2
30	-58	-50	-40	-27
40	-59	-51	-41	-18
50	-82	-76	-67	-55
60	-82	-75	-66	-54
70	-65	-58	-48	-35

TABLE B-XII. Environmental profile data example.

Phase	Source	Test Phase Definition	Temperature	Duration
A	(Given)	Ground Operation Cold Day	-54°C (TABLE B-VII)	30 min (TABLE B-VI)
B	Mission Profile	Climb to Altitude-Cold Day 30,000 feet	-50°C (TABLE B-VII)	7 minutes
C (Mission Objective)	Mission Profile	Cruise 30,000 feet	-50°C (TABLE B-VII)	23 minutes
	Mission Profile	High Performance Dive to 10,000 feet	-26°C (TABLE B-VII)	2 minutes
	Mission Profile	High Performance Mach 1.0, 10,000 feet	-26°C (TABLE B-VII)	5 minutes
	Mission Profile	Climb to 40,000 feet	-50°C (TABLE B-VII)	13 minutes
	Mission Profile	Cruise to Base	-50°C (TABLE B-VII)	35 minutes
D	Mission Profile	Idle Descent to Hot Day	71°C (TABLE B-IX)	15 minutes
E	(Given)	Ground Non-Operation Hot Day	71°C (TABLE B-VI)	*
F	(Given)	Ground Operation Hot Day	71°C (TABLE B-VI)	30 min (TABLE B-VI)
G	Mission Profile	Climb to Altitude-Hot Day 30,000 feet	56°C (TABLE B-IX)	7 minutes
H (Mission Objective)	Mission Profile	Cruise 30,000 feet	56°C (TABLE B-IX)	23 minutes
	Mission Profile	High Performance Dive to 10,000 feet	93°C (TABLE B-IX)	2 minutes
	Mission Profile	High Performance, Mach 1.0, 10,000 feet	93°C (TABLE B-IX)	5 minutes
	Mission Profile	Climb to 40,000 feet Mach No. = 0.6	5°C (TABLE B-IX)	13 minutes
	Mission Profile	Cruise to Base, Mach No. 0.6	5°C (TABLE B-IX)	35 minutes
I	Mission Profile	Idle Descent to Cold Day	-54°C (TABLE B-VII)	15 minutes
J	(Given)	Ground Non-Operational	-54°C (TABLE B-VI)	*

* Duration determined in accordance with 50.4.3.3.

TABLE B-XIII. Example temperature change rates.

Mission phase	Calculation	°C/minimum
B	$\frac{-48 + 54}{7}$	0.9*
1st C step	$\frac{-26 + 48}{2}$	11.
2nd C step	$\frac{-50 + 26}{13}$	-1.8*
D	$\frac{71 + 50}{15}$	8.1
G	$\frac{56 - 71}{7}$	-2.1*
1st H step	$\frac{93 - 56}{2}$	18.5
2nd H step	$\frac{5 - 93}{13}$	- 6.8
I	$\frac{-54 - 5}{15}$	- 3.9*

* These absolute values are less than 5°C/minute, hence 5°C/minute should be used per Note 2 of TABLE B-VI.

TABLE B-XIV. Calculations for vibration test levels.

Test phase	Altitude (feet)	Mach number	Wo (g^2/Hz)	Duration (minutes)
A Ground Operation	0	0	0	30
B Take Off	0	0	.002	1
B Climb	1-30 K	.6	.0006*	6
C Cruise	30 K	1.0	.0012	23
C Dive	30-10 K	1.0	.0035**	2
C Intercept	10 K	1.0	.0067	5
C Climb	10-40 K	1.0-.6	.002**	13
C Cruise	40 K	.6	.00006*	35
D Descent	40-0 K		.0004*	15

* In accordance with 50.4.3.2.2c value below minimum therefore no vibration is required.

** Mix vibration levels = $\frac{(.0035)\ (2) + (.002)\ 13}{15}$ determined by time weighting vibration levels for major flight phases.

TABLE B-XV. Final vibration test conditions for example.

Test Phase	Vibration Level (g^2/Hz)	Duration (minutes)
A, F	0	30
B, G	.002	1
B, G	0	0
C, H	.0012	23
C, H	.0067	5
C, H	.0022*	15
C, H	0	35
D, I	0	15
E	0	--

* Mix vibration level.

50.5.3 Vibration. For equipment installed in turbopropeller aircraft, the sine-sweep vibration envelope in FIGURE B-6 shall be used. The vibration shall be applied during the thermal cycle of FIGURE B-8 at the indicated levels for 12.5 minutes at the start of Phases B and G, and for 12.5 minutes at the start of the mission objective maneuvers during Phases C and H. If the mission profile has no maneuvers, the full vibration level shall be applied for 12.5 minutes midway during Phases C and H. For the remaining portion of the test period, the vibration level shall be reduced to 50 percent of the FIGURE B-6 levels. The frequency sweep rate shall be such as to complete one complete cycle (low frequency to high frequency to low frequency) in 12.5 minutes.

For equipment installed in helicopters without vibration isolators, the applied vibration shall be swept sinusoidal 5 Hz - 2000 Hz - 5 Hz at an acceleration level of ±2 g (peak) up to 33 Hz, then at ±5 g up to 2000 Hz. For equipment that is to be installed on vibration isolated panels or racks when the panel or rack is not available for test or equipment is tested with isolators removed, the vibration shall be at ±2 g, over the frequency range of 5 to 500 Hz. Displacement (in inches - double amplitude) ranges from 0.2 inch (5.080 mm) at 5 Hz to 0.036 inches (.9144 mm) at 33 Hz and continuing to decrease as frequency increases per FIGURE 514.2-3 of MIL-STD-810.

For equipment installed in Army helicopters, the following vibration shall be applied: Vibrate at 0.05 inch (1.27 mm) double amplitude (DA) from 5 to 24.5 Hz, 1.5 g peak from 24.5 to 500 Hz. The vibration shall be applied continuously from 5 to 500 to 5 Hz. The sweep rate shall be logarithmic and shall take 15 minutes to go from 5 to 500 to 5 Hz. This shall be applied once for every hour of equipment operation.

50.5.4 Thermal stress. The general thermal test profile to be used is shown in FIGURE B-8. This profile simulates both a cold day and hot day mission, and together form one cycle. The thermal cycle is continuously repeated until the end of the test. Prior to the start of the first thermal cycle, or after storage at room ambient, the equipment shall be allowed to cold soak for 1 1/2 hours at the low temperature of the start of the next thermal cycle. The temperature extremes and procedure for constructing a thermal profile shall in general be the same as used in RG-503 for jet aircraft, but limited to the mission requirements as flown by turbocraft and helicopters.

50.5.5 Humidity stress. Humidity should be specified to simulate the warm, moist atmospheric conditions especially prevalent in tropic climates. Moisture can be induced directly into equipment during flight in a humid atmosphere. Installed equipment is also subject to condensation, freezing and frosting as a result of climatic temperature-humidity conditions.

50.5.5.1 Supplementally cooled equipment. The chamber air humidity shall be in accordance with 50.4.3.4.2. The supplemental cooling air may be dried so that its dewpoint is 3°C ±10° below the lower of the supplemental air or chamber air temperatures.

50.5.5.2 Chamber air humidity. Humidity shall be injected into the test chamber from a steam source or other humidity source and controlled by a dewpoint controller or other humidity measuring instrumentation. The humidity shall be introduced into the chamber in Phase D and shall be increased as the chamber air temperature increases, keeping the dewpoint less than the chamber air temperature. The dewpoint temperature shall be raised to 31°C or greater and maintained and controlled through Phases E and F of FIGURE B-3 of this appendix. At the end of Phase F, no further injection of moisture is required for the other profile phases and humidity shall be uncontrolled. This humidity procedure shall be repeated for each test cycle, phase D, E, and F. Drying of chamber air shall not be accomplished at any time during a test cycle.

50.6 Combined environments for air-launched weapons and assembled external stores.

50.6.1 General. Environmental criteria and guidelines for air-launched weapons and equipment mounted therein are presented in detail in MIL-STD-1670 and will not be repeated here. Using that information, test conditions and levels can be readily derived, given the equipment mission application. Much of the information given and the techniques used are also applicable to external stores carried on aircraft. Additional data on vibration for external stores carried on airplanes and on helicopters are presented in MIL-STD-810, Method 514, TABLES 514-IV and 514-IVA.

APPENDIX C

STATISTICAL TEST PLANS

10. GENERAL

10.1 Scope. This appendix covers the statistical test plans and the selection and use of these plans. Operational characteristic curves are given for Probability Ratio Sequential Test (PRST), fixed length and All Equipments test. Also expected test time curves are presented for the PRST plans.

10.2 Purpose. The purpose of this appendix is to provide information and guidance in the selection and application of the statistical test plans provided for reliability qualification and acceptance testing.

20. SELECTION OF TEST PLAN

20.1 Probability ratio sequential test plans (PRST). Standard PRST plans should be used when a sequential test plan with normal (10 to 20 percent) producer and consumer risks are desired. Short-run high risk PRST plans may be used when a sequential test plan is desired, but circumstances require the use of a short test and both the producer and the consumer are willing to accept relatively high decision risks. PRST plans will accept material with a high MTBF or reject material with a very low MTBF more quickly than fixed length test plans having similar risks and discrimination ratios. However, they provide no estimate of true MTBF, and total test time may vary significantly. Therefore, program cost and schedule must be planned to truncation.

20.2 Fixed length test plans. The fixed length test plans must be used when the exact length and costs of test must be known beforehand and when it is necessary to obtain an estimate of the true MTBF demonstrated by the test as well as an accept/reject decision. Most of the fixed length tests are based on the same values of α and β and discrimination ratios as the PRST plans.

20.3 All equipment production reliability acceptance test. The all equipment reliability acceptance test is used when it is desired to have each equipment subjected to a reliability acceptance test.

20.4 Considerations in selecting a test plan.

20.4.1 General. In the selection of a test plan (or test plans) for a specific procurement, it is recommended that the user of this document consider:

a. Tactical importance of the equipment
b. The maturity of the equipment and its planned life
c. Funding of the program
d. Delivery schedule and available test time
e. Availability of test facilities
f. Decision risks desired (see 30.3)
g. Effect of design ratio on value of θ_0
h. Predicted or demonstrated MTBF of similar equipment
i. Performance of cost-time trade-off studies when considering the use of fixed length test plans (by comparing the operating characteristic curves and expected times for test completion)

30. CHARACTERISTICS OF THE STATISTICAL TEST PLANS

30.1 Summary. TABLE C-I summarizes the test plans and indicates the expected duration of the test provided the true equipment MTBF equals the design MTBF (θ_0) for the PRST plans.

TABLE C-I. Summary of test plans.

Test plan	Nominal Decision risks		Discrimination ratio	Time to accept Decision in MTBF (θ_1 multiple)		
PRST				Minimum	Expected * if true MTBF=θ_0	Maximum (Truncation)
IC	10%		1.5	6.60	25.95	49.5
IIC	20%		1.5	4.19	11.4	21.9
IIIC	10%		2.0	4.40	10.2	20.6
IVC	20%		2.0	2.80	4.8	9.74
VC	10%		3.0	3.75	6.0	10.35
VIC	20%		3.0	2.67	3.42	4.50
VIIC	30%		1.5	3.15	5.1	6.8
VIIIC	30%		2.0	1.72	2.6	4.5
FIXED LENGTH	α	β				
IXC	10%	10%	1.5	45.0	**	
XC	10%	20%	1.5	29.9	**	
XIC	20%	20%	1.5	21.1	**	
XIIC	10%	10%	2.0	18.8	**	
XIIIC	10%	20%	2.0	12.4	**	
XIVC	20%	20%	2.0	7.8	**	
XVC	10%	10%	3.0	9.3	**	
XVIC	10%	20%	3.0	5.4	**	
XVIIC	20%	20%	3.0	4.3	**	
XIXC	30%	30%	1.5	8.0	**	
XXC	30%	30%	2.0	3.7	**	
XXIC	30%	30%	3.0	1.1	**	

* The probability that the decision will be an accept decision equals (1-α). The probability that the decision will be a reject decision equals (α).

** For fixed-length tests, the expected time to a decision is actually slightly less than the value given for truncation due to the possibility that the test will terminate in a reject decision prior to truncation.

Note: If n equipments are placed on test, the elapsed test time is reduced approximatley by factor of n but the total equipment test time remains as stated in the above table.

30.2 Basis of the test plans. The reliability test plans are based on two sets of parameters: decision risks and discrimination ratio; both are covered below. The accept/reject criteria of Test Plans IC-VIIIC are based on Wald's Probability Ratio Sequential Test (PRST); the work of B. Epstein in Statistical Techniques in Life Testing, Technical Report Number 3, prepared under Contract Number 2163(00)(NR-042-018) for the Office of Naval Research; and the work of B. Epstein, A. A. Patterson and C. R. Qualls given in the paper, The exact Analysis of Sequential Life Tests with Particular Application to AGREE Plans, presented at the 1963 Aerospace Reliability and Maintainability Conference. The accept/reject criteria of all the test plans are based on the assumption that the underlying distribution of times between failure is exponential. MIL-HDBK-108 may be consulted for details on other test plans.

30.3 Decision risks. The consumer's decision risk, β, is the probability that the equipments with MTBF equal to the lower test MTBF, θ_1, will be accepted by the test plan. The producer's decision risk, α, is the probability that equipments with MTBF equal to the upper test MTBF, θ_0, will be rejected by the test plan. In general, accept/reject criteria with low decision risks will require testing for a greater number of equipment operating hours. Low decision risks provide good protection against the test rejecting satisfactory equipment or accepting unsatisfactory equipment. For each of the truncated sequential plans (PRST), the exact risks were calculated. Shifts in the accept/reject lines and truncation points were made to bring the true risks closer to the desired (designated) risks and to make the two risks more nearly equal for each plan. The decision risks of Test Plan XVIIIC vary with the total test time (that is, truncation point) and have little significance as a reason for choosing this plan. However, it is interesting to note that β approaches 0 percent, as total test time of Test Plan XVIIIC is increased.

30.4 Discrimination ratio. The discrimination ratio, as used herein, is the ratio of the upper test MTBF (θ_0) to the lower test MTBF (θ_1). The discrimination ratio is a measure of the power of the test in reaching a decision quickly and is an essential parameter, together with the decision risks, in defining a sequential type accept/reject criteria. In general, the higher the discrimination ratio, the shorter the test. The discrimination ratio (and corresponding test plan) must be chosen carefully to prevent the resulting θ_0 from becoming unattainable due to design limitations.

30.5 Standard PRST accept-reject criteria and operating characteristic OC curves. FIGURES C-1 through C-8 present graphically the accept-reject criteria for the standard PRST test plans. Charts 1-8 present the OC and Expected Test Time (ETT) curves for each of Test Plans IC through VIII C. The OC curves plot values of true θ_1 (MTBF) versus the probability of acceptance. The ETT curves plot values of true θ_1 (MTBF) versus expected test time (time to an accept or reject decision of each θ_1).

30.6 All equipment production reliability acceptance test, Test Plan XVIIIC. FIGURE C-9 presents the accept-reject criteria for Test Plan XVIIIC and Chart 9 shows the corresponding OC curves.

30.7 Standard fixed-length test plans and OC curves. Test plans IXC to XXIC are summarized in TABLES IV and V of Section 4.0 and corresponding OC curves are located in Charts 10 to 21. The Poisson formula for the OC curve is listed below.

$$P_a(\theta) = \sum_{K=0}^{r_o-1} \frac{\left(\frac{T_o}{\theta}\right)^K \exp}{K!} \left(\frac{-T_o}{\theta}\right)^*$$

where

$P(\theta$ = the probability of accepting items with a mean life of θ,
r_o = the critical (reject) number of failures,
T_o = the test termination time.

The quantity r_o is determined so that

$$P(\theta_0) \geq 1 - \alpha, P(\theta_1) \geq \beta.$$

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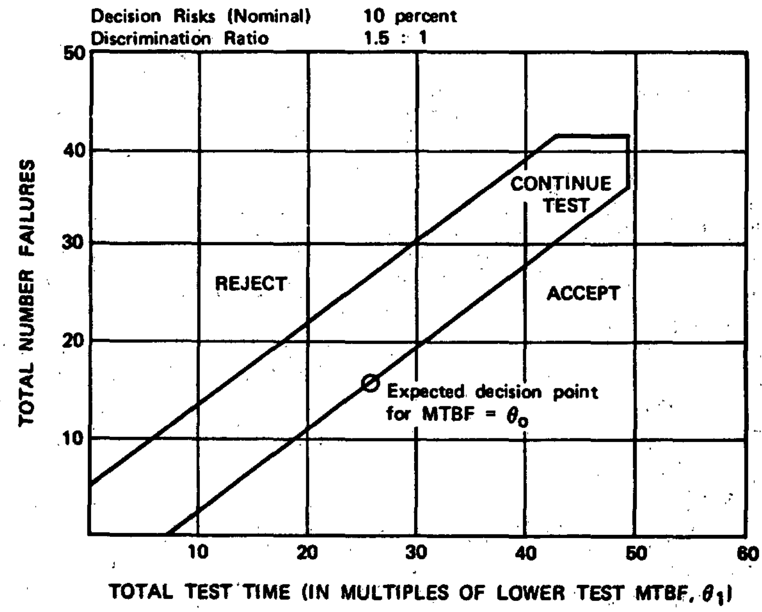
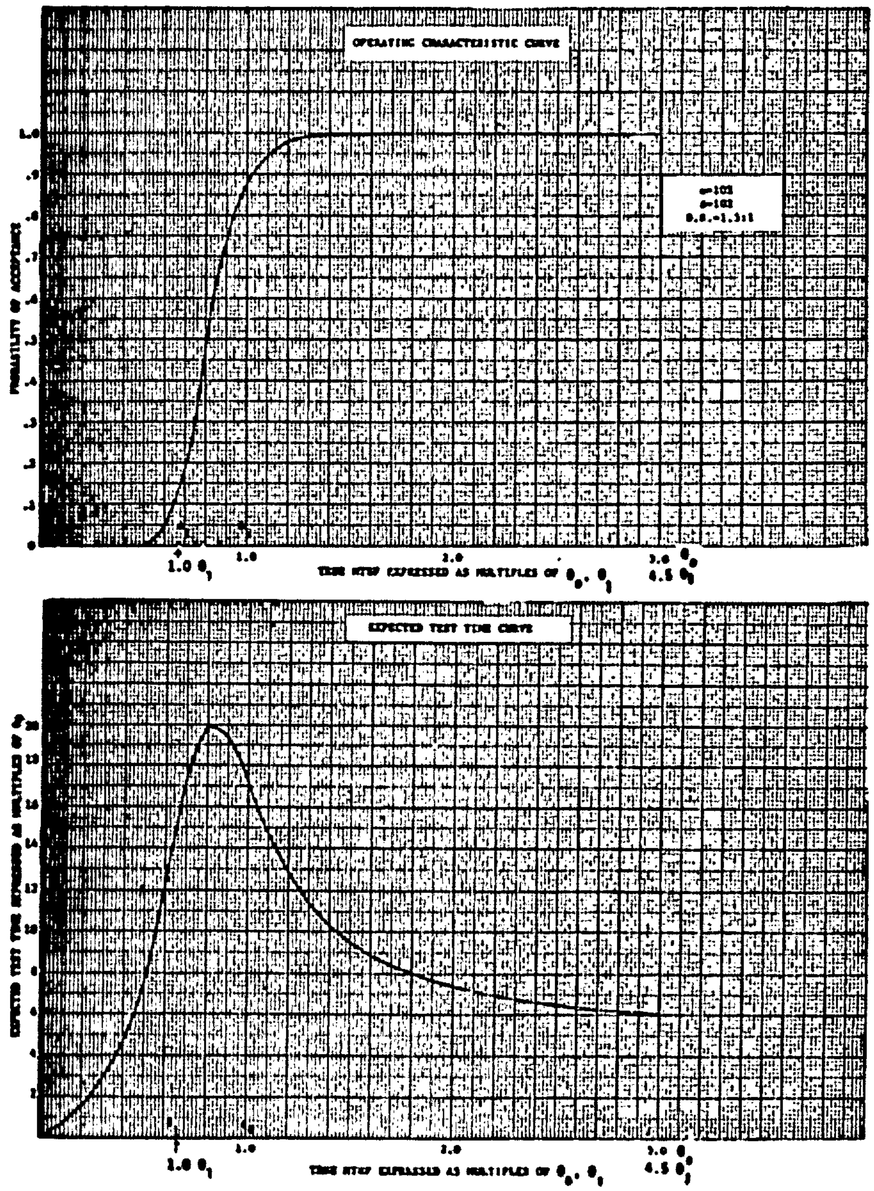


Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)	Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)
0	N/A	6.60	21	18.92	32.15
1	N/A	7.82	22	20.13	33.36
2	N/A	9.03	23	21.35	34.58
3	N/A	10.25	24	22.56	35.79
4	N/A	11.46	25	23.78	37.01
5	N/A	12.68	26	24.99	38.22
6	.68	13.91	27	26.21	39.44
7	1.89	15.12	28	27.44	40.67
8	3.11	16.34	29	28.65	41.88
9	4.32	17.55	30	29.85	43.10
10	5.54	18.77	31	31.08	44.31
11	6.75	19.98	32	32.30	45.53
12	7.97	21.20	33	33.51	46.74
13	9.18	22.41	34	34.73	47.96
14	10.40	23.63	35	35.94	49.17
15	11.61	24.84	36	37.16	49.50
16	12.83	26.06	37	38.37	49.50
17	14.06	27.29	38	39.59	49.50
18	15.27	28.50	39	40.82	49.50
19	16.49	29.72	40	42.03	49.50
20	17.70	30.93	41	49.50	N/A

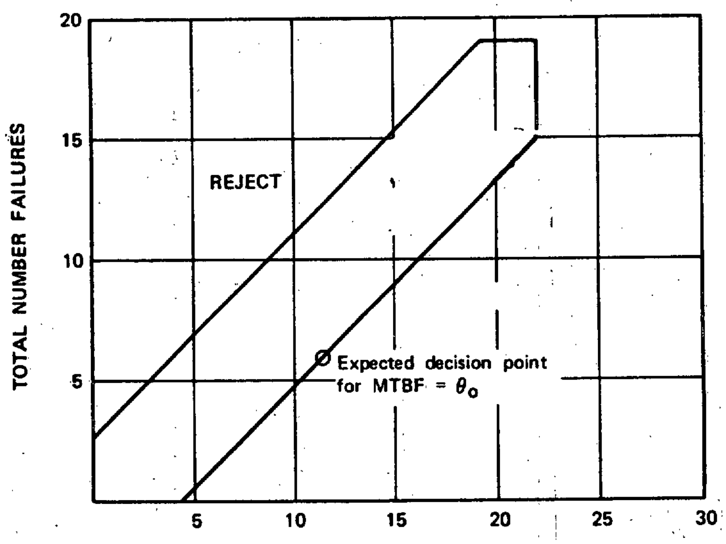
* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

FIGURE C-1. Accept-reject criteria for Test Plan IC.

CHART 1 - TEST PLAN IC



Decision Risks (Nominal) 20 percent
Discrimination Ratio 1.5 : 1

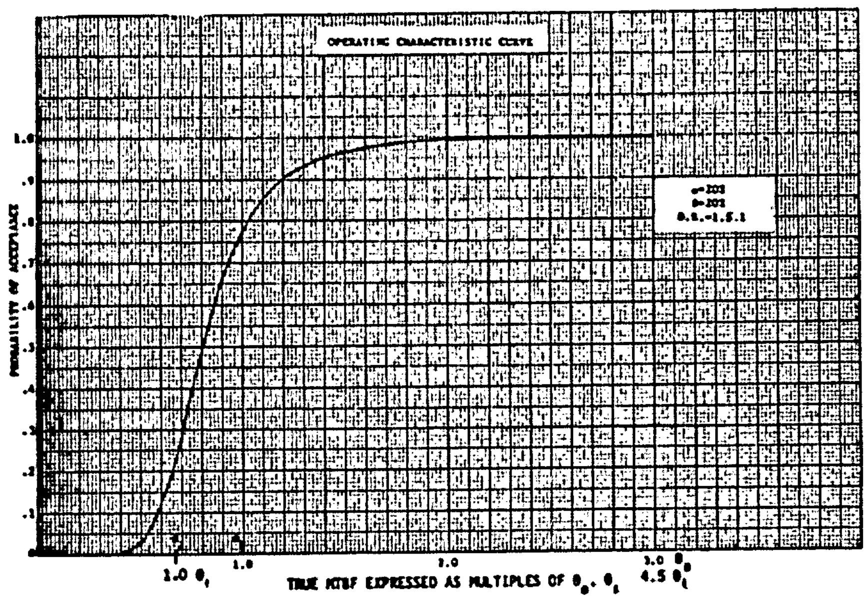


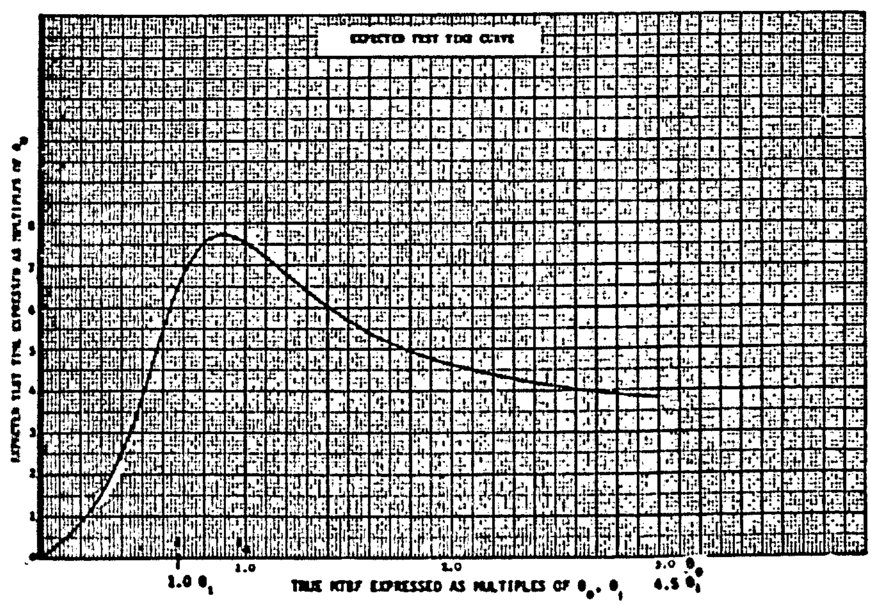
Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)	Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)
0	N/A	4.19	10	8.76	16.35
1	N/A	5.40	11	9.98	17.57
2	N/A	6.62	12	11.19	18.73
3	.24	7.83	13	12.41	19.99
4	1.46	9.05	14	13.62	21.21
5	2.67	10.26	15	14.84	21.90
6	3.90	11.49	16	16.05	21.90
7	5.12	12.71	17	17.28	21.90
8	6.33	13.92	18	18.50	21.90
9	7.55	15.14	19	21.90	N/A

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

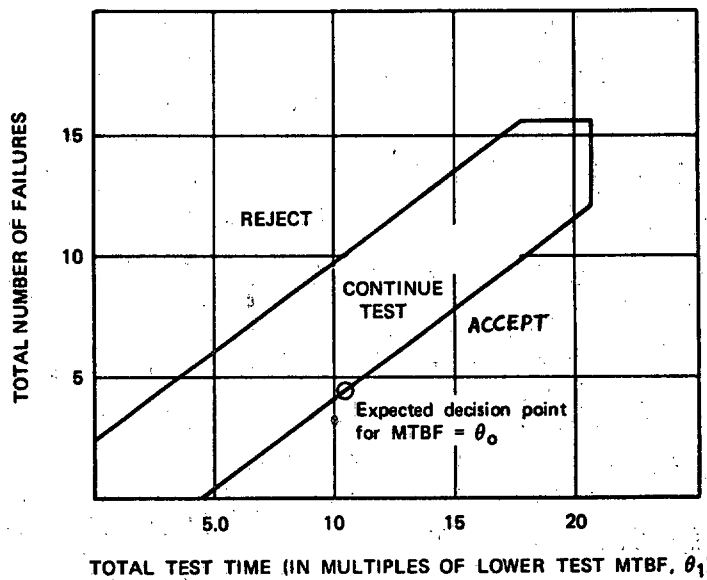
FIGURE C-2. Accept-reject criteria for Test Plan IIC.

CHART 2 - TEST PLAN IIC





Decision Risks (Nominal) 10 percent
Discrimination Ratio 2.0 : 1

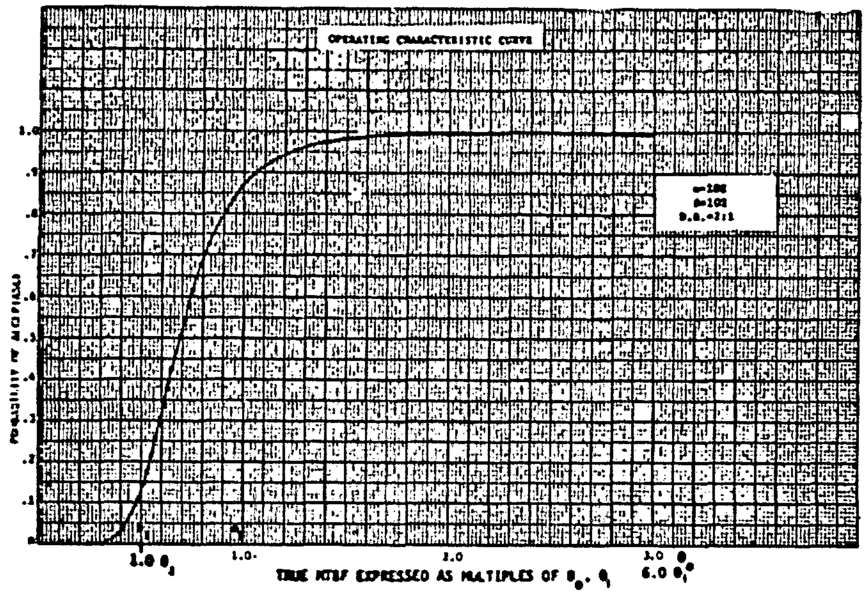


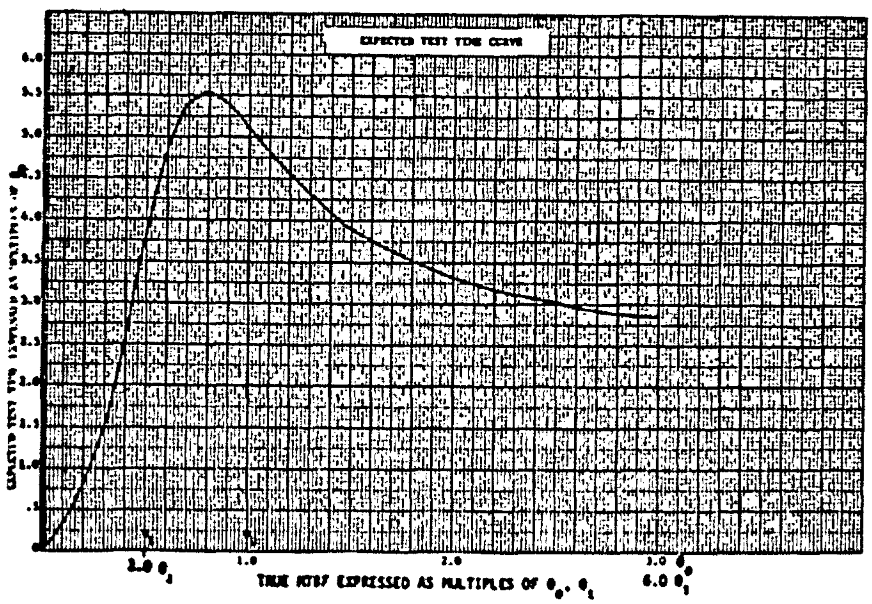
Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)	Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)
0	N/A	4.40	9	9.02	16.88
1	N/A	5.79	10	10.40	18.26
2	N/A	7.18	11	11.79	19.65
3	.70	8.56	12	13.18	20.60
4	2.08	9.94	13	14.56	20.60
5	3.48	11.34	14	15.94	20.60
6	4.86	12.72	15	17.34	20.60
7	6.24	14.10	16	20.60	N/A
8	7.63	15.49			

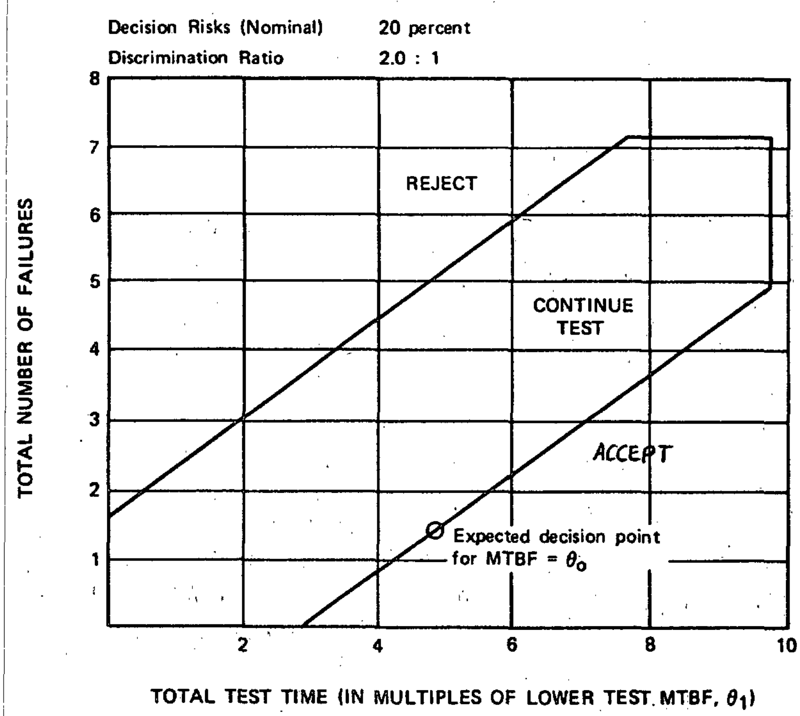
* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

FIGURE C-3. Accept-reject criteria for Test Plan IIIC.

CHART 3 - TEST PLAN IIIC





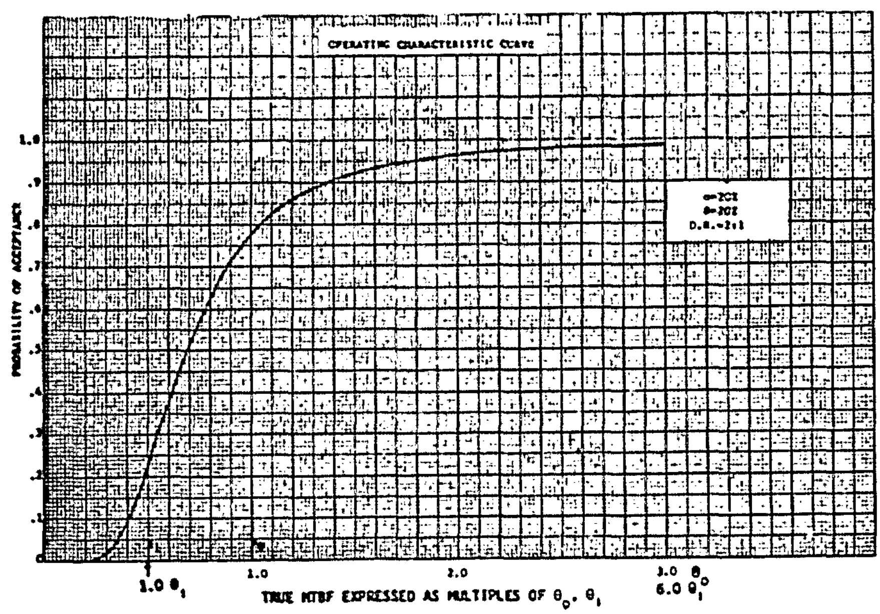


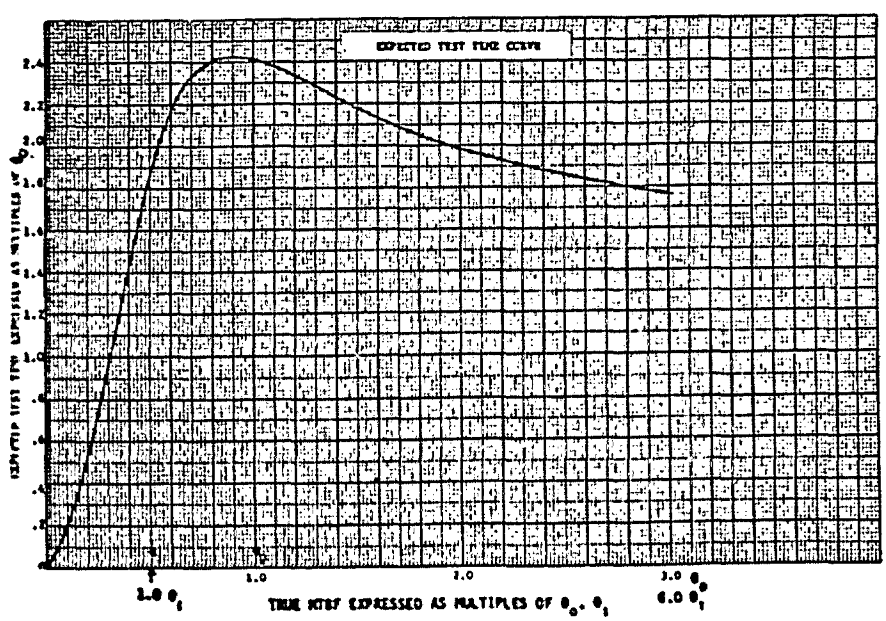
Number of Failures	Total Test Time* Reject (Equal or less)	Accept (Equal or more)
0	N/A	2.80
1	N/A	4.18
2	.70	5.58
3	2.08	6.96
4	3.46	8.34
5	4.86	9.74
6	6.24	9.74
7	7.62	9.74
8	9.74	N/A

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

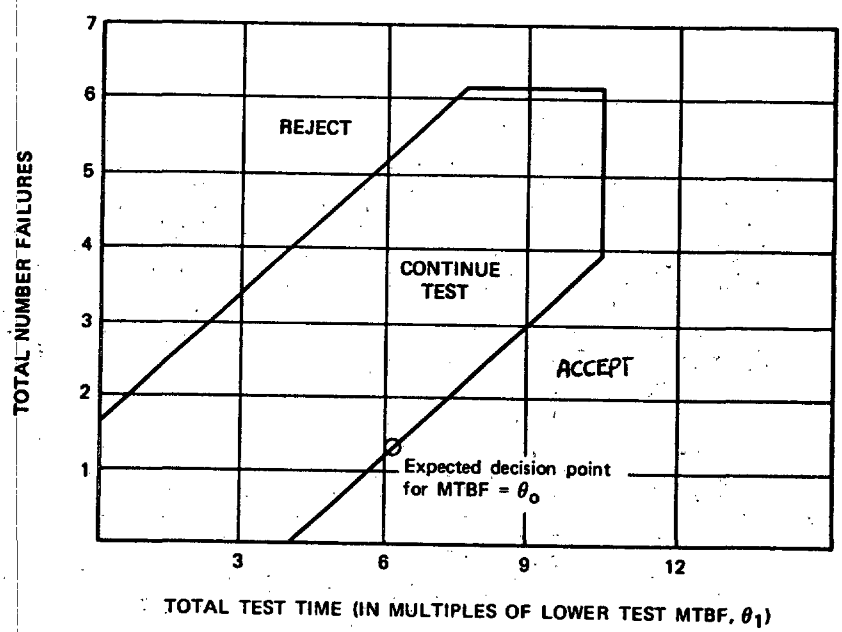
FIGURE C-4. Accept-reject criteria for Test Plan IVC.

CHART 4 - TEST PLAN IVC





Decision Risks (Nominal) 10 percent
Discrimination Ratio 3.0 : 1



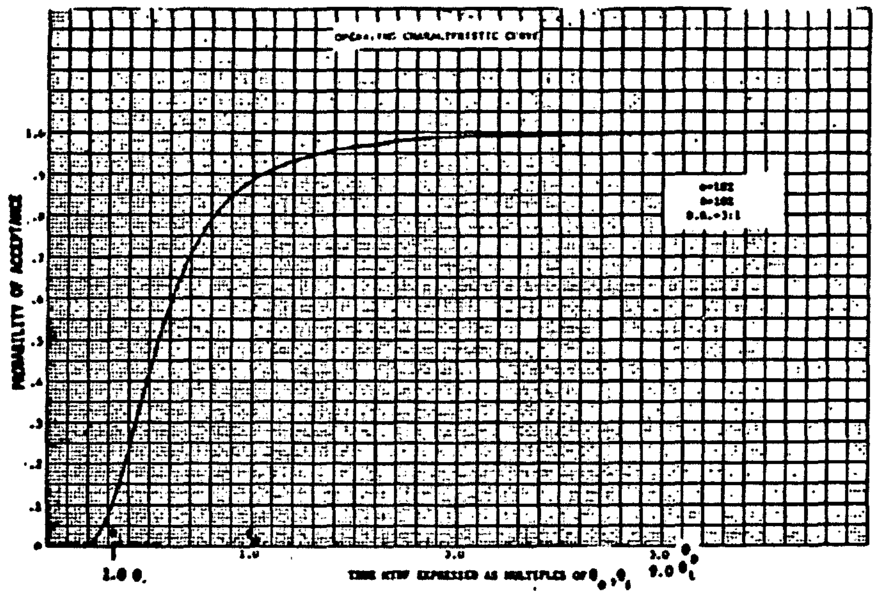
Total Test Time*

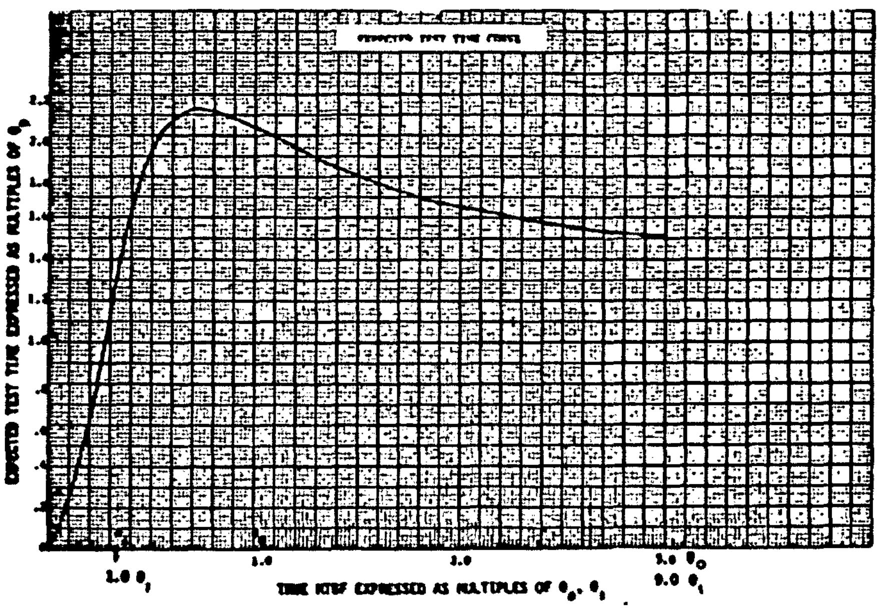
Number of Failures	Reject (Equal or less)	Accept (Equal or more)
0	N/A	3.75
1	N/A	5.40
2	.57	7.05
3	2.22	8.7
4	3.87	10.35
5	5.52	10.35
6	7.17	10.35
7	10.35	N/A

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

FIGURE C-5. Accept reject criteria for Test Plan VC.

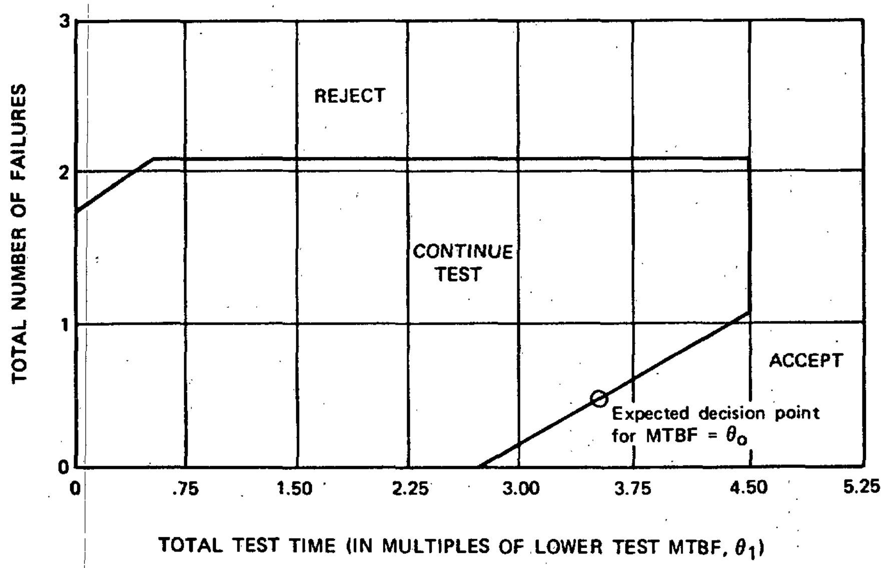
CHART 5 - TEST PLAN VC





Decision Risks (Nominal) 20 percent

Discrimination Ratio 3.0 : 1



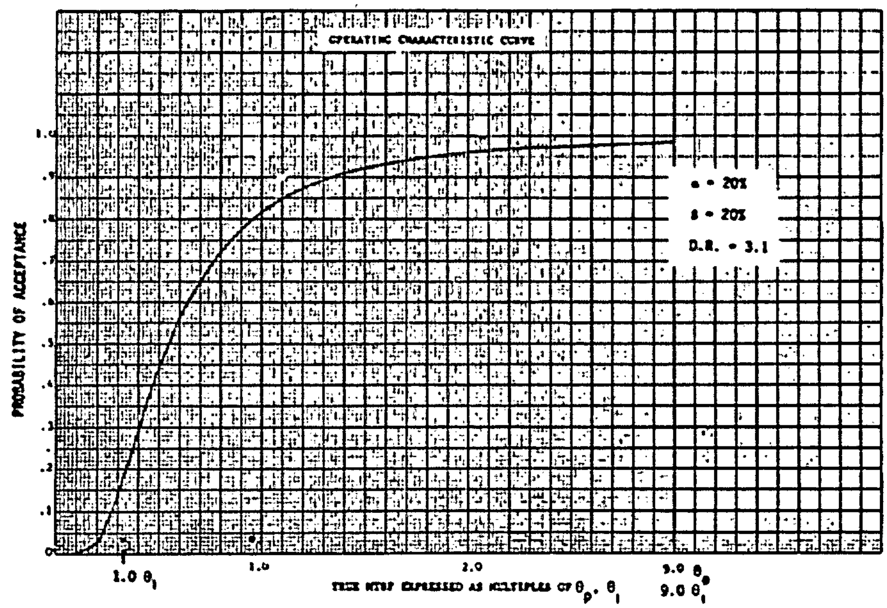
Total Test Time*

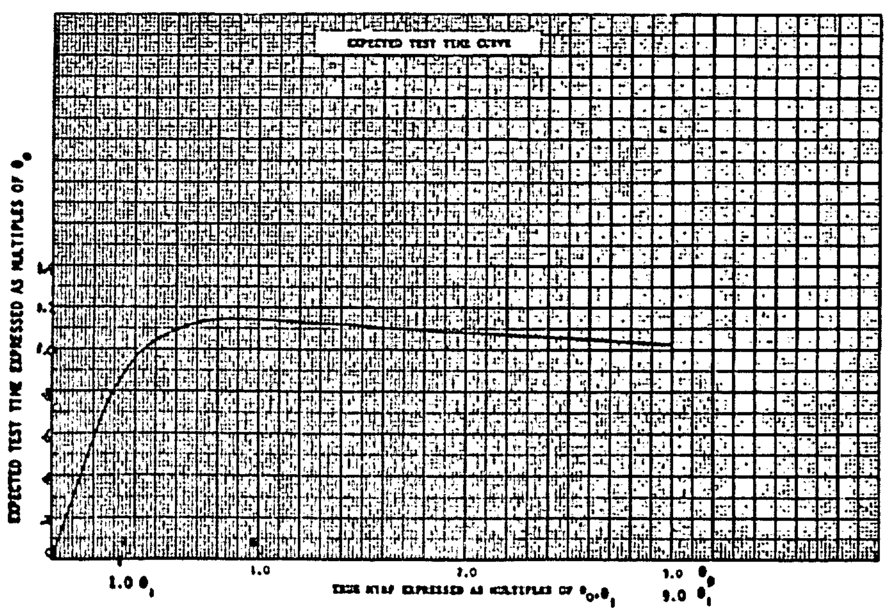
Number of Failures	Reject (Equal or less)	Accept (Equal or more)
0	N/A	2.67
1	N/A	4.32
2	.36	4.50
3	4.50	N/A

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

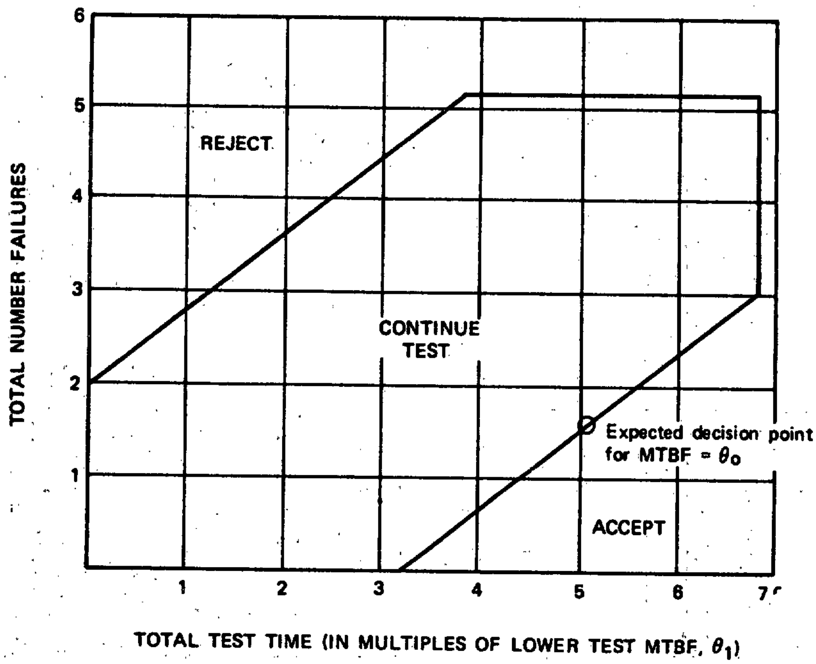
FIGURE C-6. Accept-reject criteria for Test Plan VIC.

CHART 6 - TEST PLAN VIC





Decision Risks (Nominal) 30 percent
Discrimination Ratio 1.5 : 1

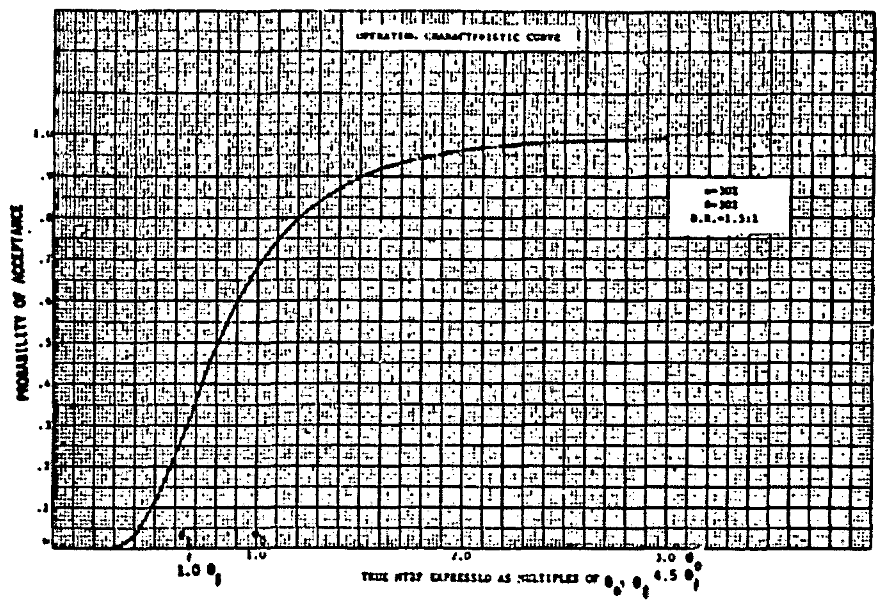


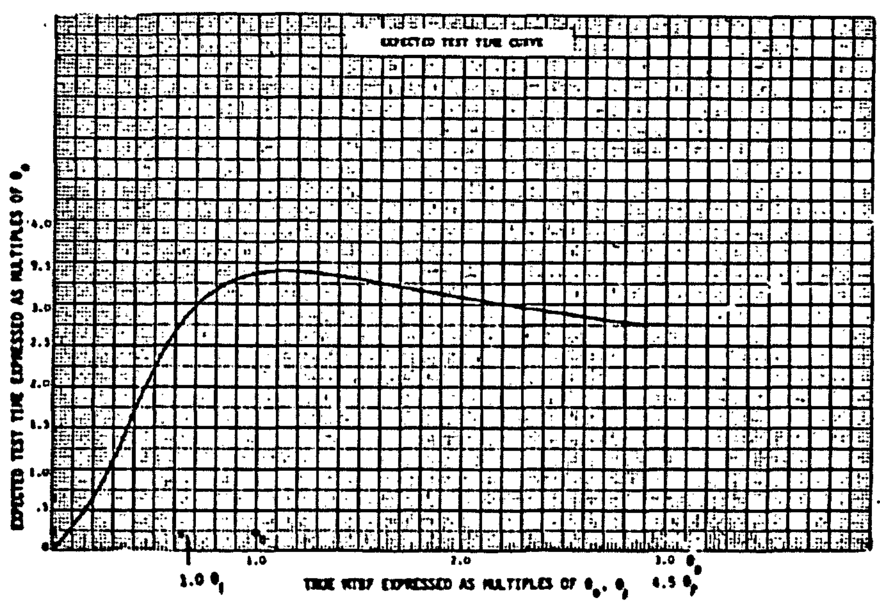
Number of Failures	Total Test Time* Reject (Equal or less)	Accept (Equal or more)
0	N/A	3.15
1	N/A	4.37
2	N/A	5.58
3	1.22	6.80
4	2.43	6.80
5	3.65	6.80
6	6.80	N/A

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

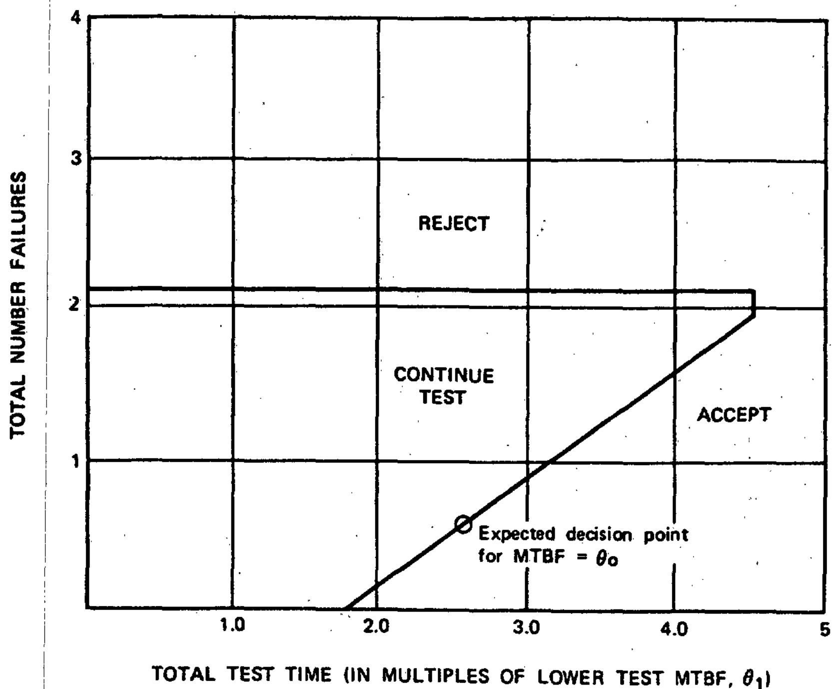
FIGURE C-7. Accept-reject criteria for Test Plan VIIC.

CHART 7 - TEST PLAN VIIC





Decision Risks (Nominal) 30 percent
Discrimination Ratio 2.0: 1



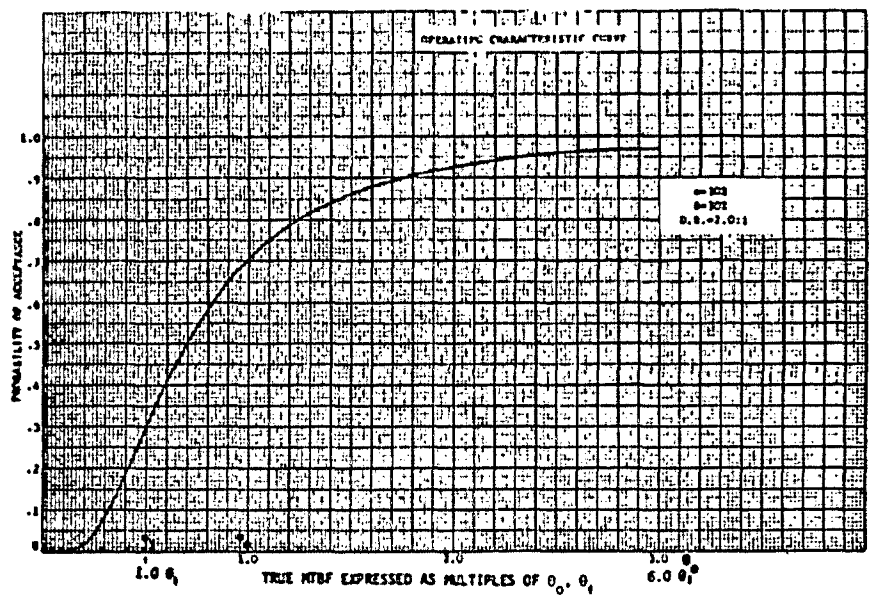
Total Test Time*

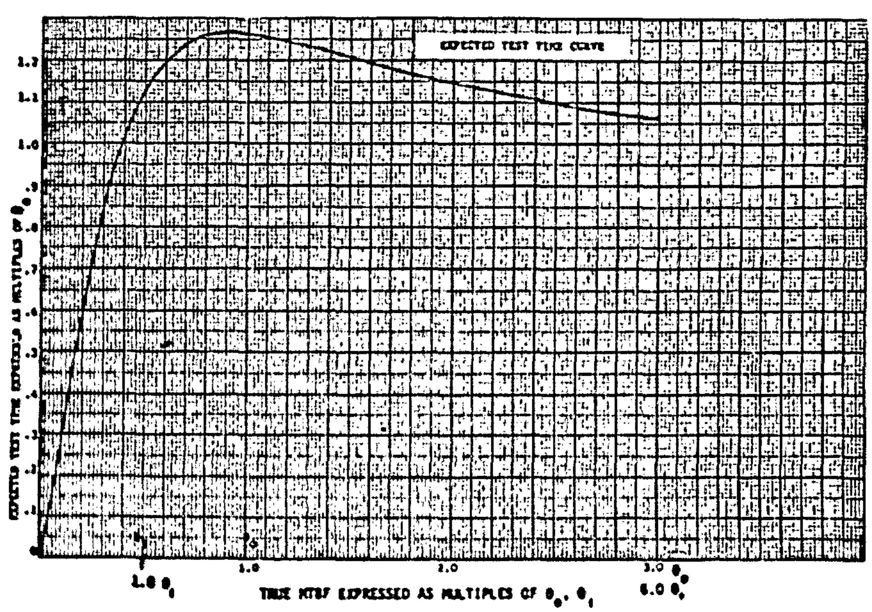
Number of Failures	Reject (Equal or less)	Accept (Equal or more)
0	N/A	1.72
1	N/A	3.10
2	N/A	4.50
3	4.5	N/A

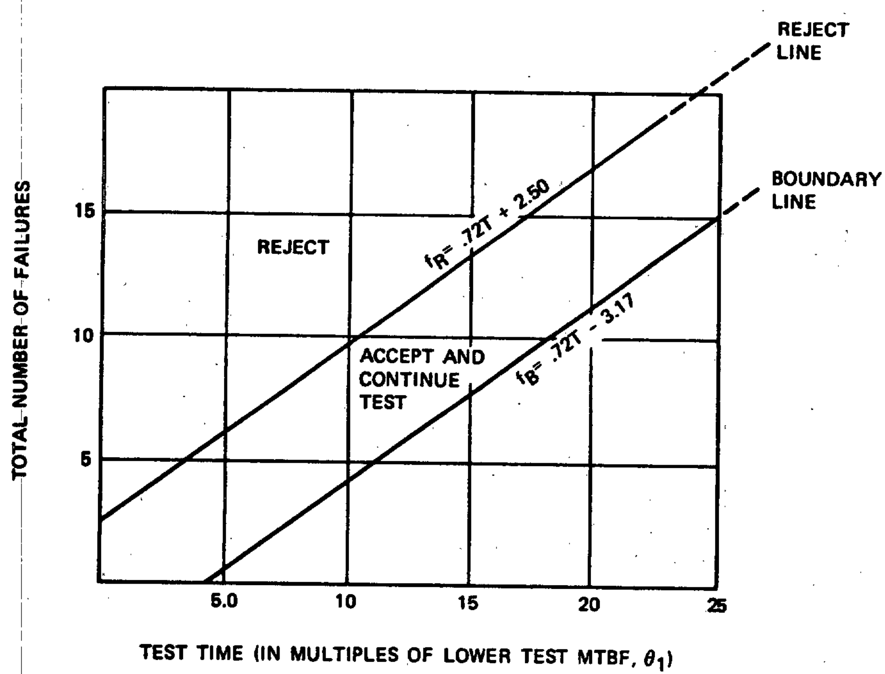
*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

FIGURE C-8. Accept-reject criteria for Test Plan VIIIC.

CHART 8 - TEST PLAN VIIIC





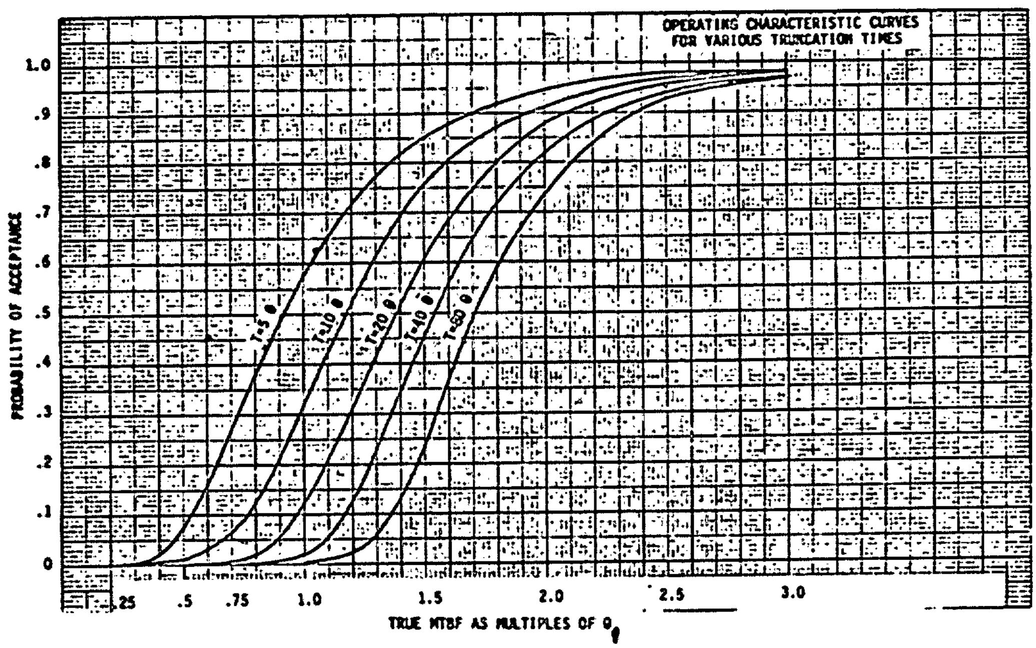


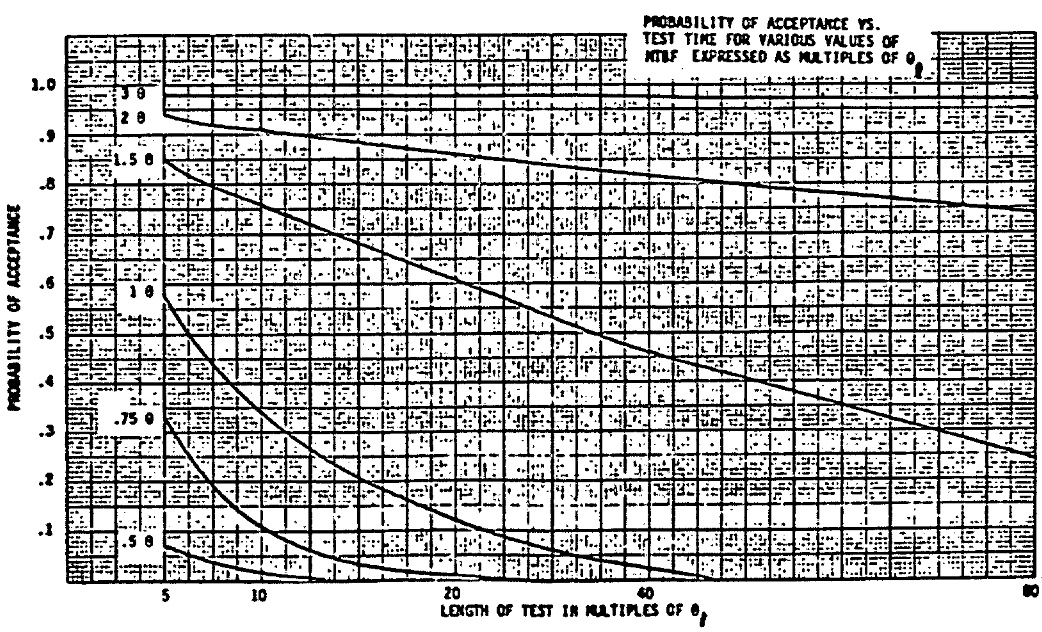
Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)	Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)
0	N/A	4.40	9	9.02	16.88
1	N/A	5.79	10	10.40	18.26
2	N/A	7.18	11	11.79	19.65
3	.70	8.56	12	13.18	21.04
4	2.08	9.94	13	14.56	22.42
5	3.48	11.34	14	ETC	ETC
6	4.86	12.72	15	.	.
7	6.24	14.10	16	.	.
8	7.63	15.49	.	.	.

*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE C-9. Reject-Accept criteria for Test Plan XVIIIC.

CHART 9 - TEST PLAN XVIIIC.





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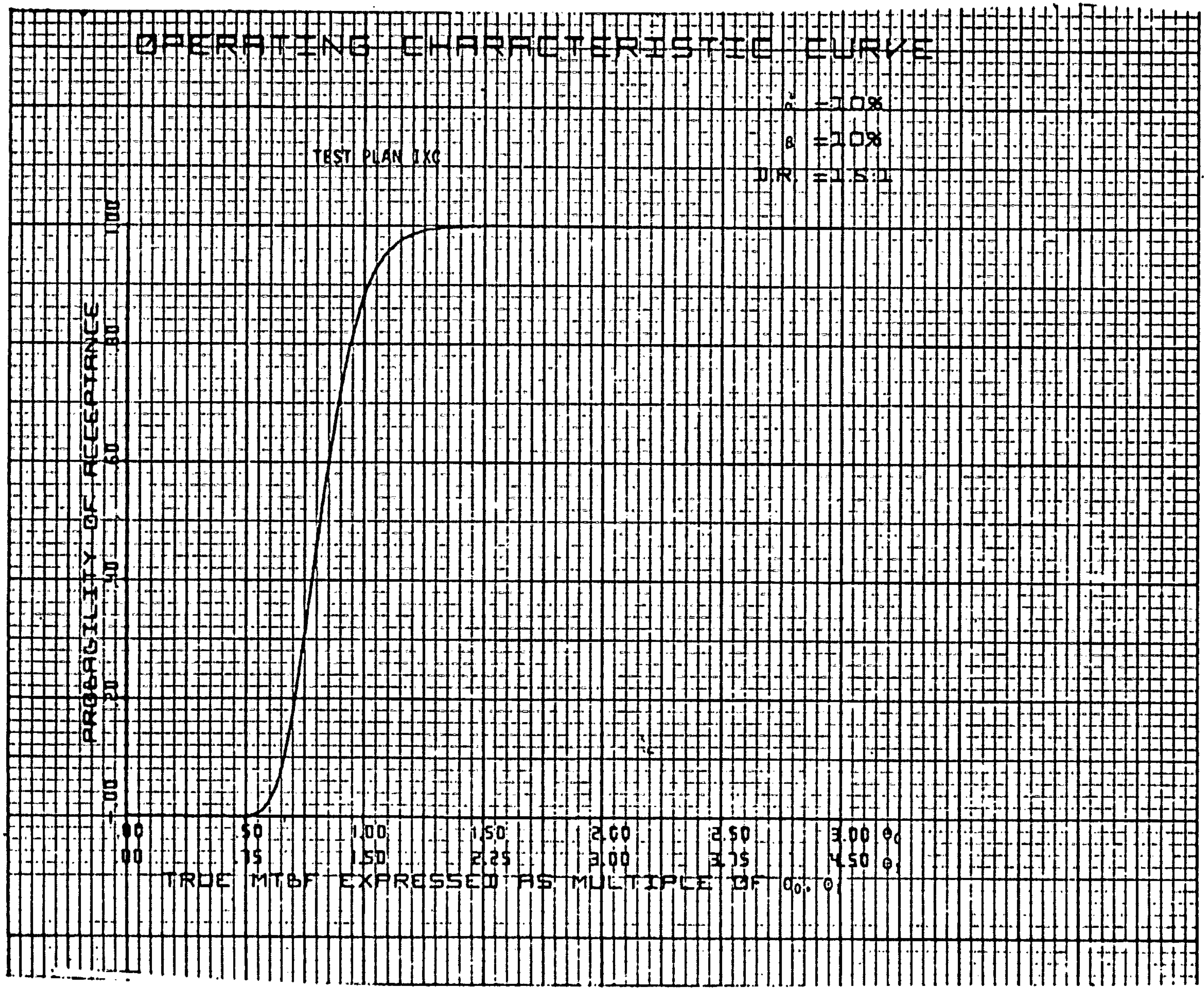

OPERATING CHARACTERISTIC CURVE
α =10%
β =10%
D.R. =1.5:1
TEST PLAN IXC
PROBABILITY OF ACCEPTANCE
0.0
20
40
60
80
100
.00
.50
1.00
1.50
2.00
2.50
3.00 θ₀
.00
.75
1.50
2.25
3.00
3.75
4.50 θ₁
TRUE MTBF EXPRESSED AS MULTIPLE OF θ₀, θ₁

CHART 10

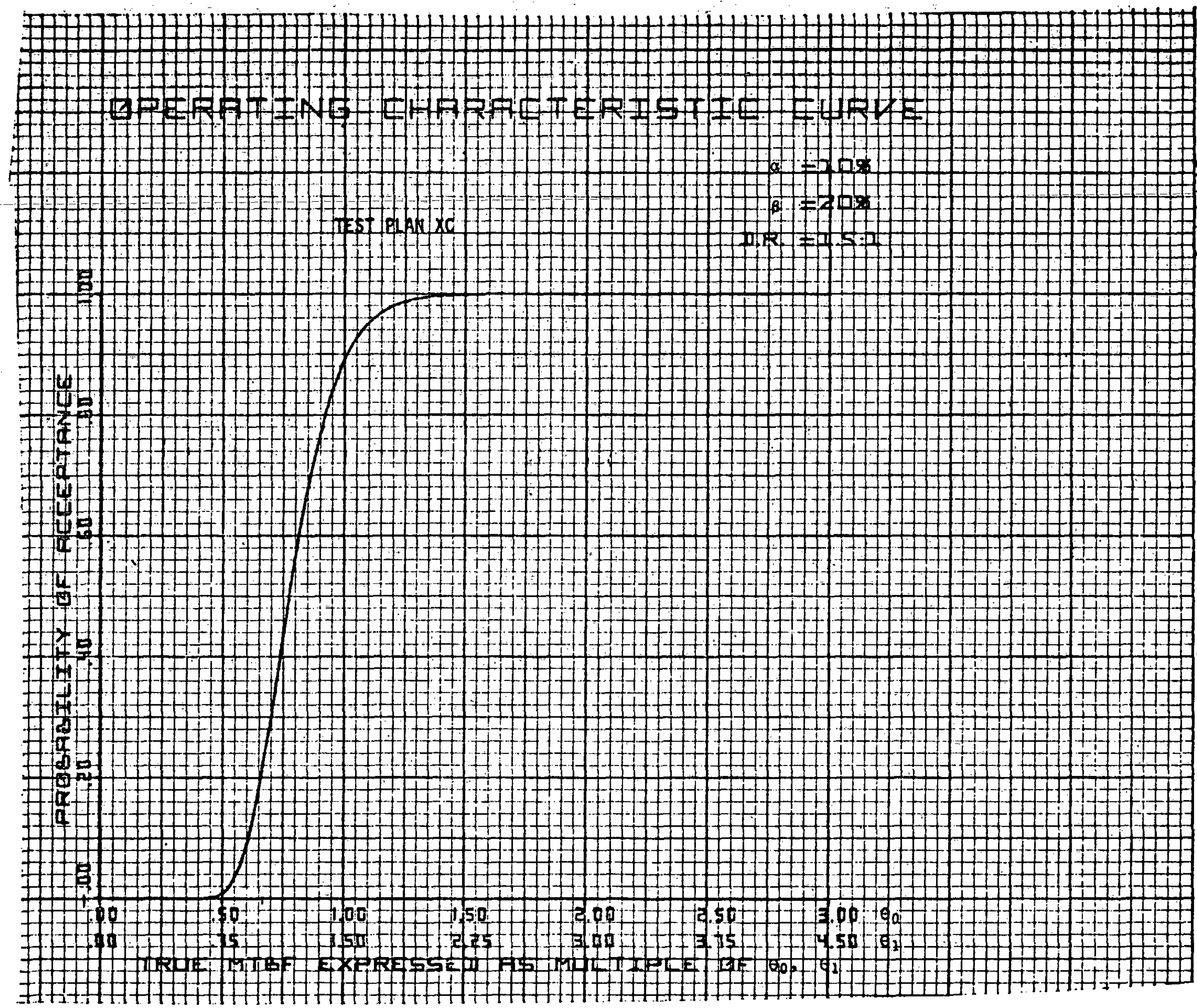

OPERATING CHARACTERISTIC CURVE
α = 10%
β = 20%
D.R. = 1.5:1
TEST PLAN XC
PROBABILITY OF ACCEPTANCE
1.00
.80
.60
.40
.20
.00
.00 .50 1.00 1.50 2.00 2.50 3.00 θ_0
.00 .75 1.50 2.25 3.00 3.75 4.50 θ_1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ_0, θ_1

CHART 11

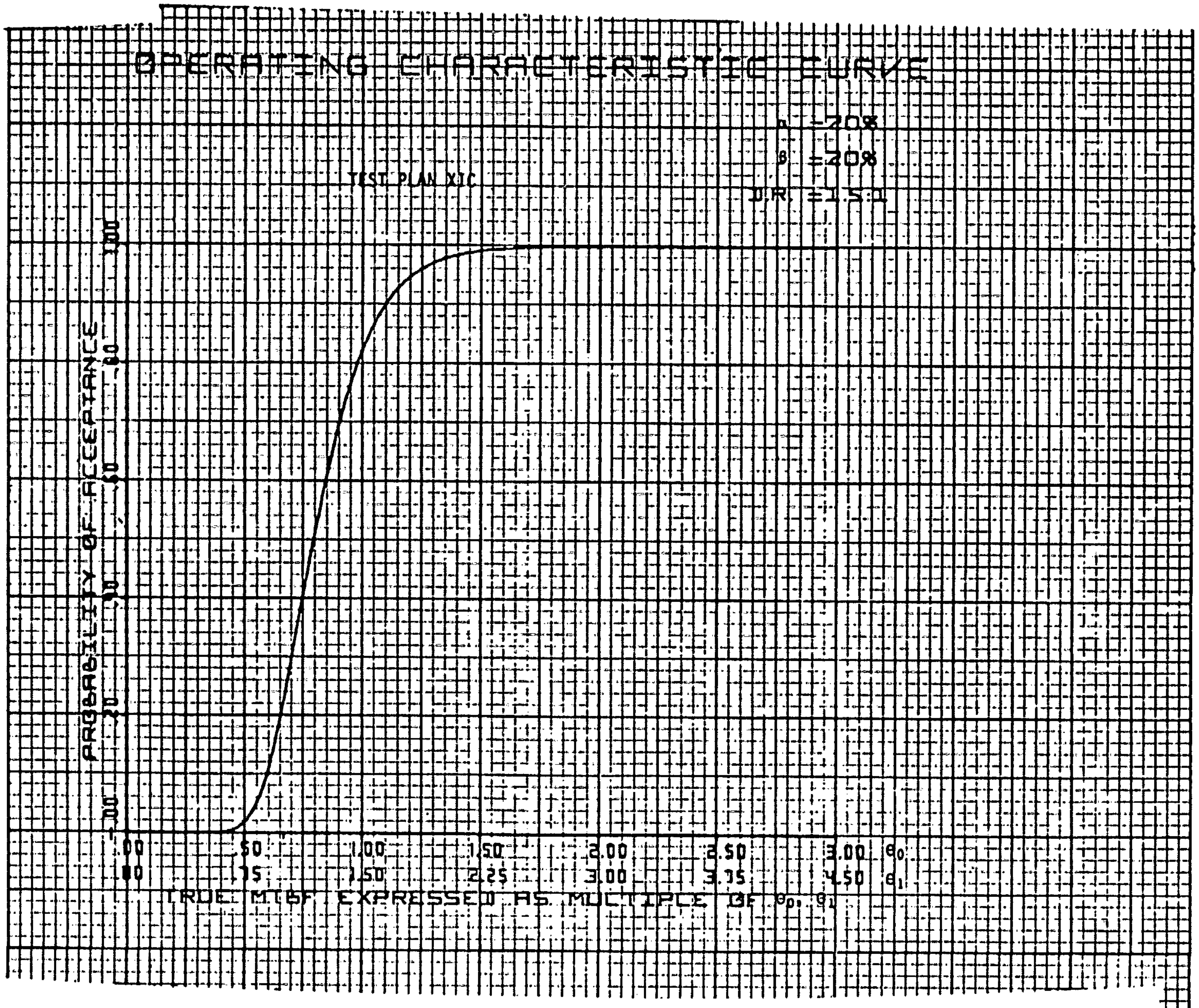

OPERATING CHARACTERISTIC CURVE
α =20%
β =20%
D.R. =1.5:1
TEST PLAN XIC
PROBABILITY OF ACCEPTANCE
1.00
.80
.60
.40
.20
0.0
.00 .50 1.00 1.50 2.00 2.50 3.00 θ0
.00 .75 1.50 2.25 3.00 3.75 4.50 θ1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ0, θ1

CHART 12

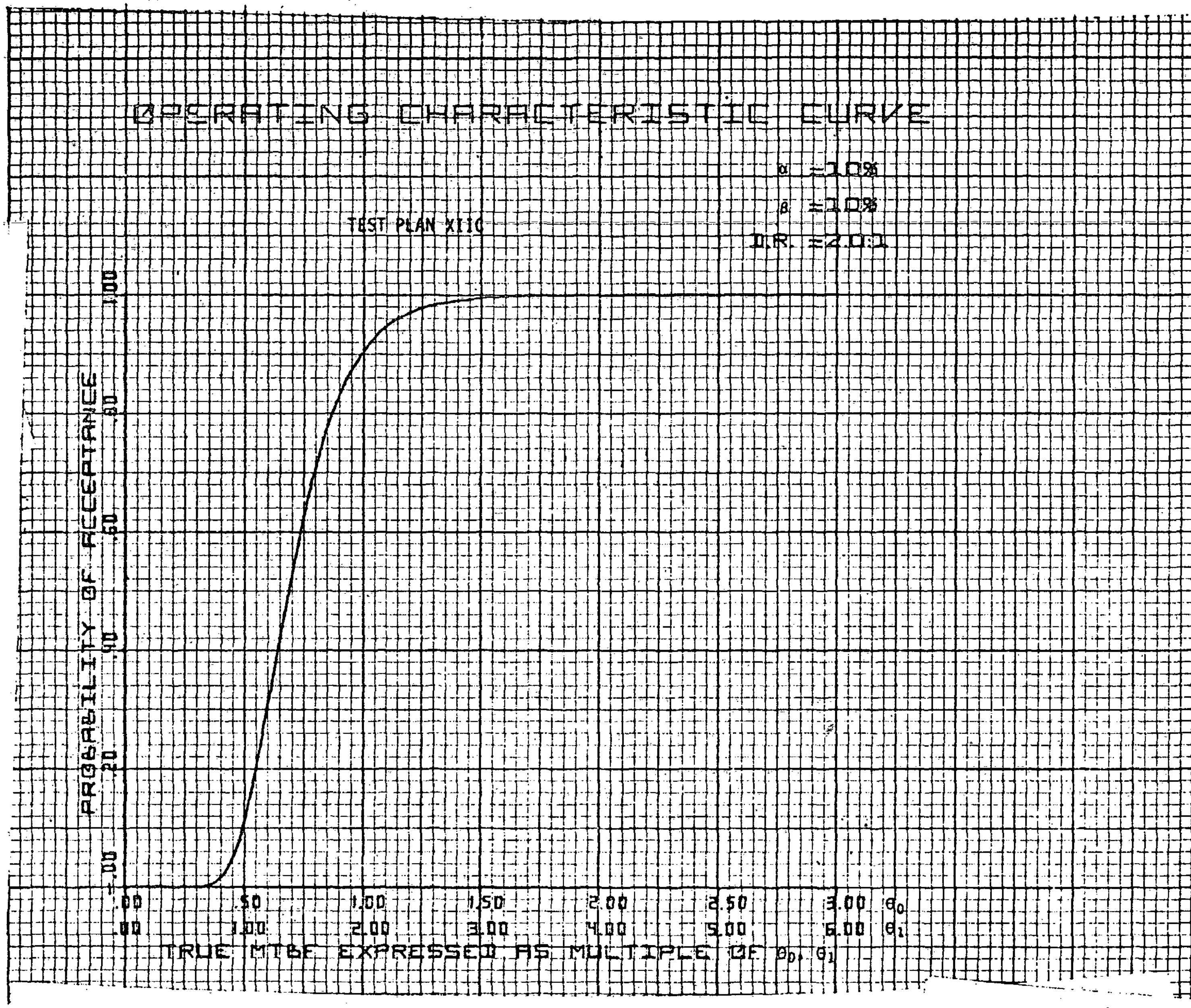

OPERATING CHARACTERISTIC CURVE
α =10%
β =10%
D.R. =2.0:1
TEST PLAN XIIC
PROBABILITY OF ACCEPTANCE
.00
.20
.40
.60
.80
1.00
.00 .50 1.00 1.50 2.00 2.50 3.00 θ_0
.00 1.00 2.00 3.00 4.00 5.00 6.00 θ_1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ_0, θ_1

CHART 13

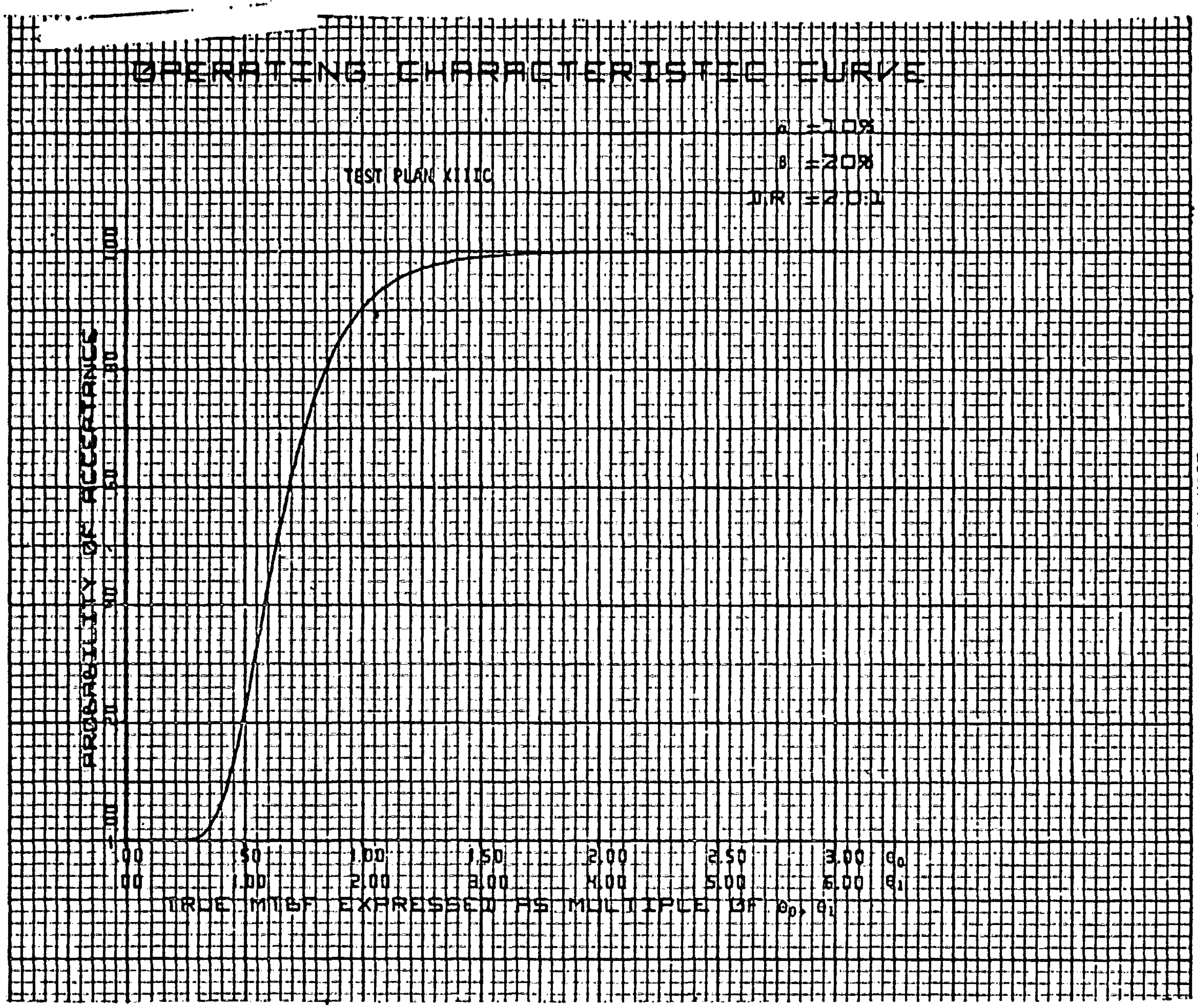

OPERATING CHARACTERISTIC CURVE
α =10%
β =20%
D.R =2.0:1
TEST PLAN XIIIC
PROBABILITY OF ACCEPTANCE
.00 .50 1.00 1.50 2.00 2.50 3.00 θ0
.00 1.00 2.00 3.00 4.00 5.00 6.00 θ1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ0, θ1

CHART 14

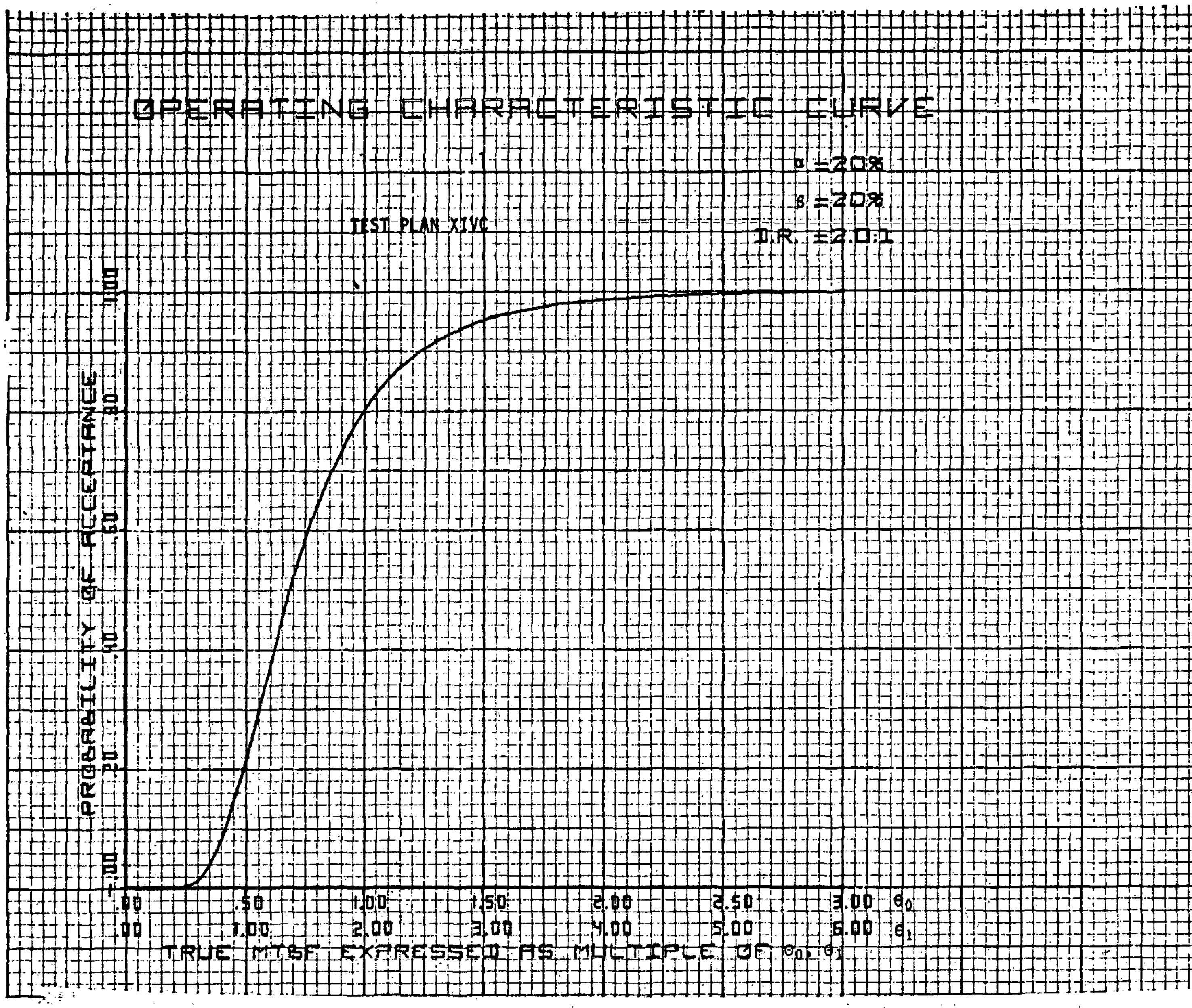

OPERATING CHARACTERISTIC CURVE
α = 20%
β = 20%
D.R. = 2.0:1
TEST PLAN XIVC
PROBABILITY OF ACCEPTANCE
1.00
.80
.60
.40
.20
0.00
.00 .50 1.00 1.50 2.00 2.50 3.00 Θ0
.00 1.00 2.00 3.00 4.00 5.00 6.00 Θ1
TRUE MTBF EXPRESSED AS MULTIPLE OF Θ0, Θ1

CHART 15

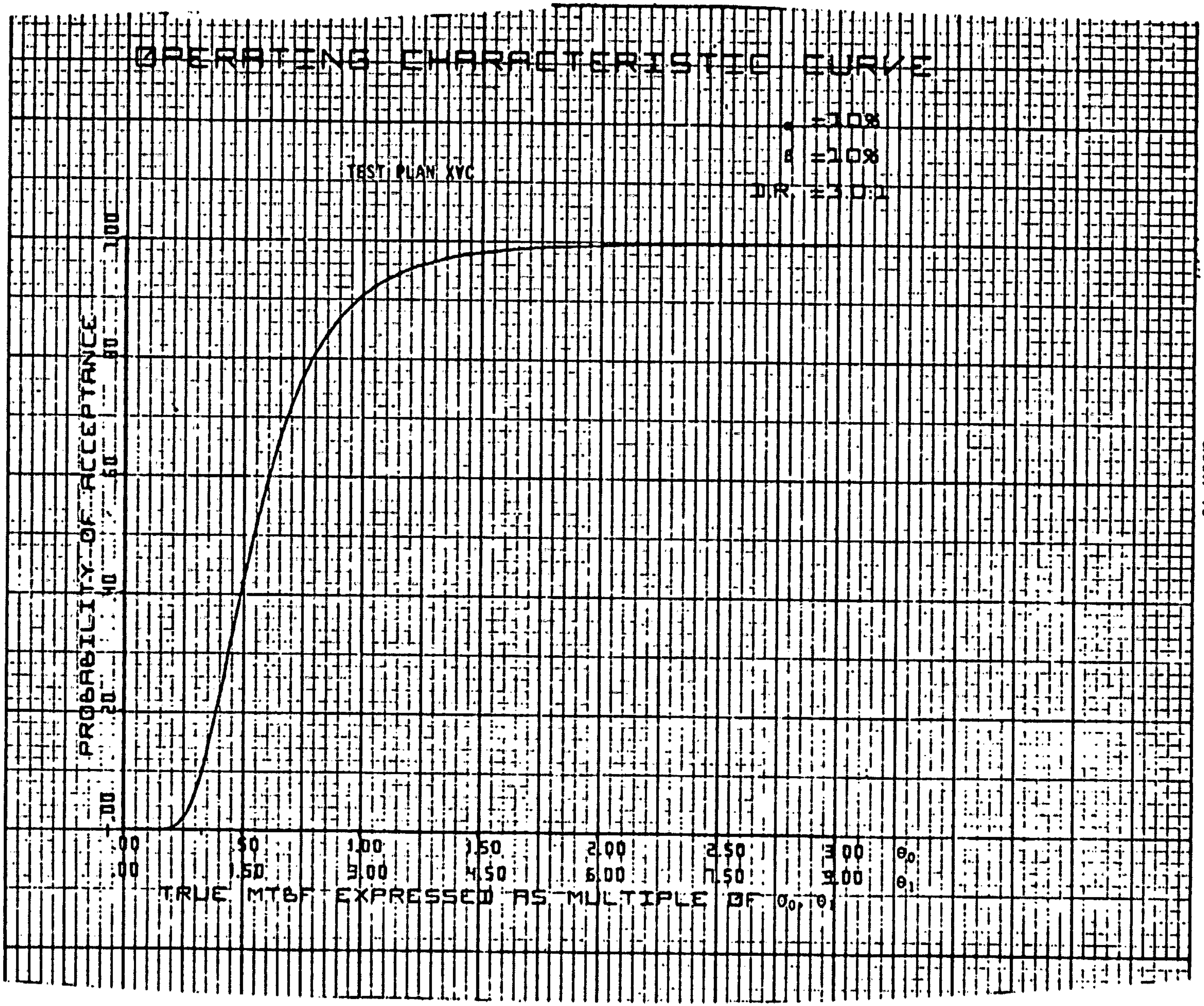

OPERATING CHARACTERISTIC CURVE
α =10%
β =10%
D.R. =3.0:1
TEST PLAN XVC
PROBABILITY OF ACCEPTANCE
.00
20
40
60
80
100
.00 .50 1.00 1.50 2.00 2.50 3.00 θ0
.00 1.50 3.00 4.50 6.00 7.50 9.00 θ1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ0, θ1

CHART 16

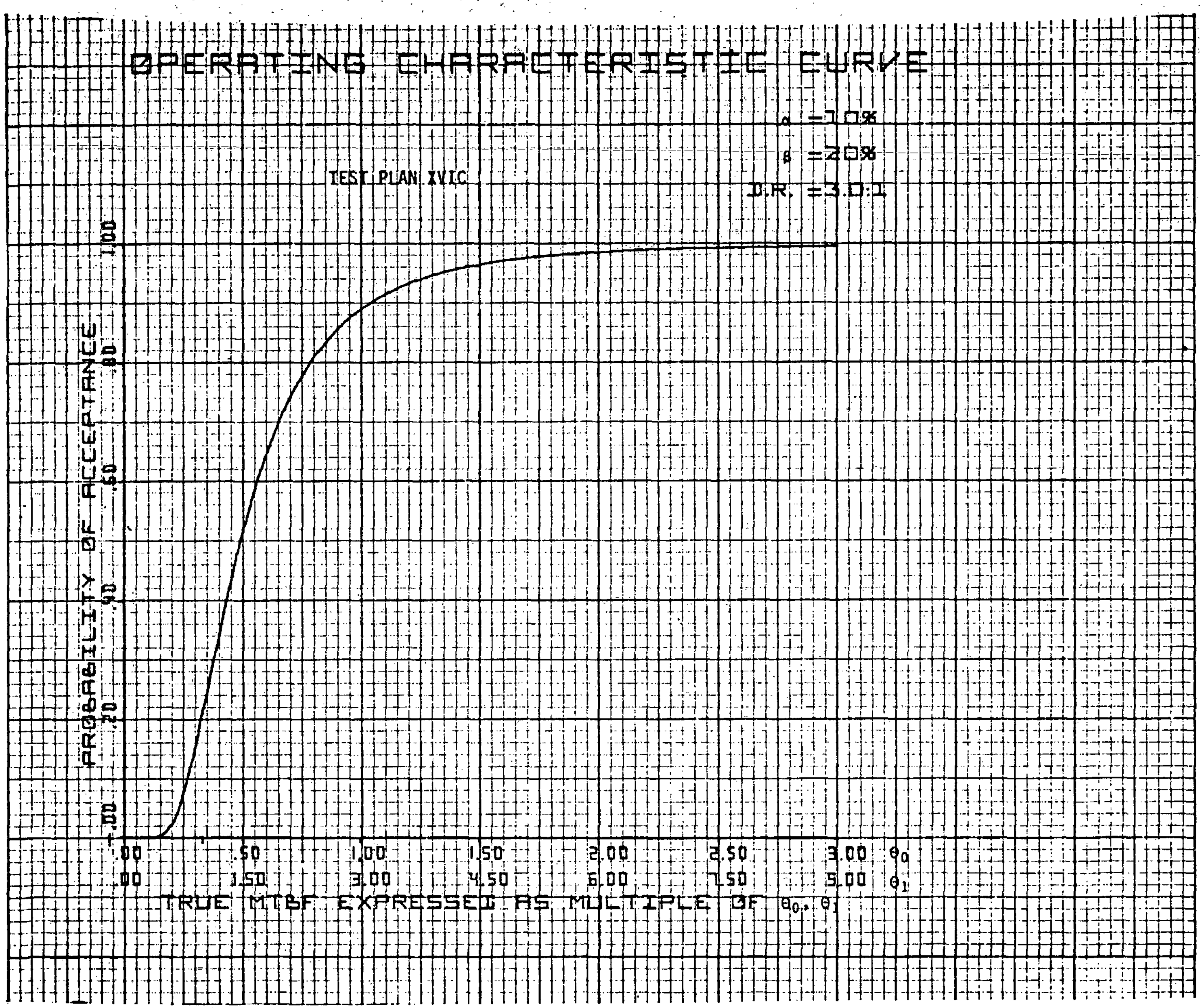

OPERATING CHARACTERISTIC CURVE
α = 10%
β = 20%
D.R. = 3.0:1
TEST PLAN XVIC
PROBABILITY OF ACCEPTANCE
1.00
.80
.60
.40
.20
.00
.00 .50 1.00 1.50 2.00 2.50 3.00 θ0
.00 1.50 3.00 4.50 6.00 7.50 9.00 θ1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ0, θ1

CHART 17

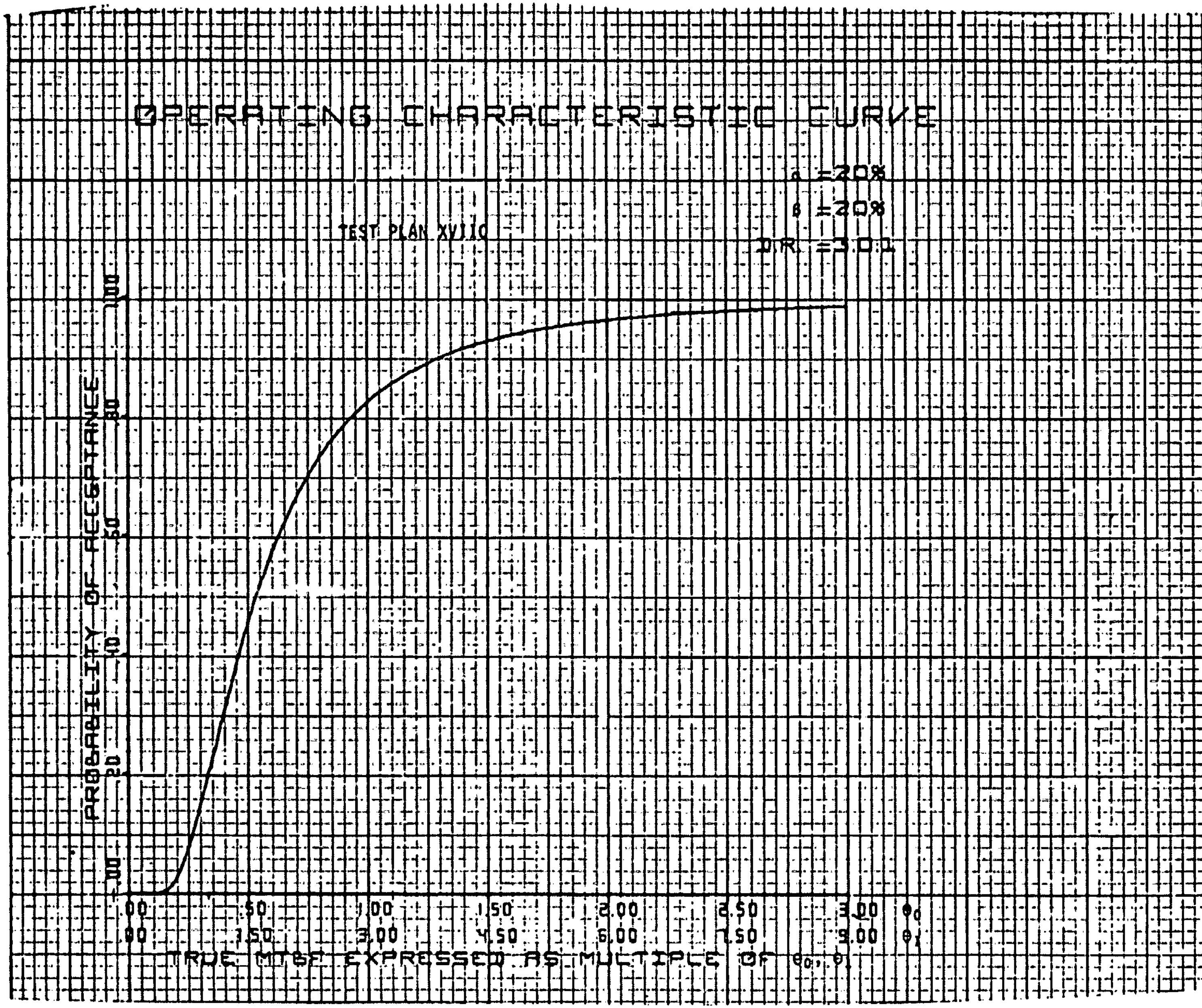

OPERATING CHARACTERISTIC CURVE
α =20%
β =20%
DR =3.0:1
TEST PLAN XVIIC
PROBABILITY OF ACCEPTANCE
100
80
60
40
20
00
.00
.50
1.00
1.50
2.00
2.50
3.00
θ_0
.00
1.50
3.00
4.50
6.00
7.50
9.00
θ_1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ_0, θ_1

CHART 18

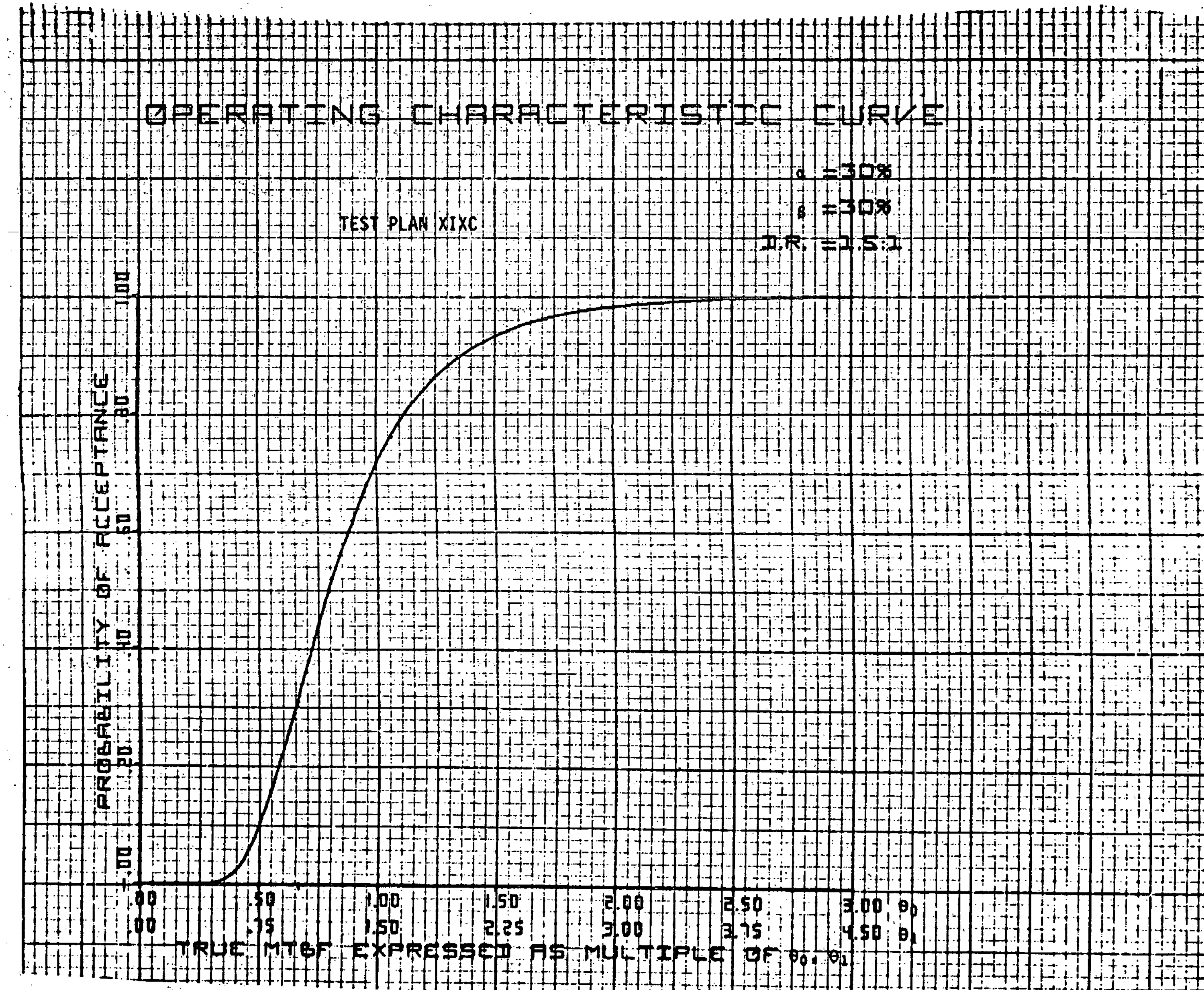

OPERATING CHARACTERISTIC CURVE
α =30%
β =30%
D.R. =1.5:1
TEST PLAN XIXC
PROBABILITY OF ACCEPTANCE
.00 .50 1.00 1.50 2.00 2.50 3.00 θ_0
.00 .75 1.50 2.25 3.00 3.75 4.50 θ_1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ_0, θ_1

CHART 19

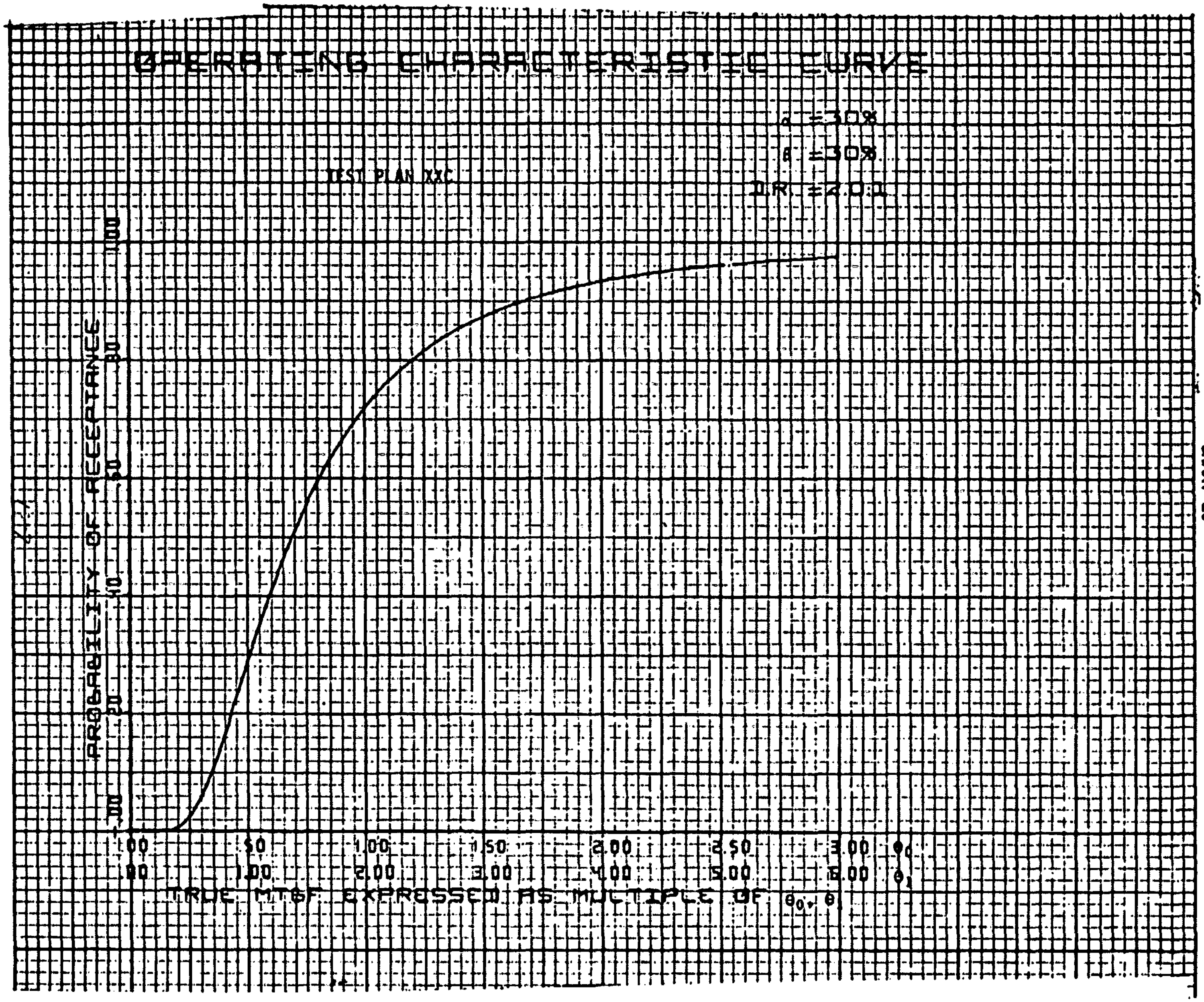

OPERATING CHARACTERISTIC CURVE
α =30%
β =30%
TEST PLAN XXC
DR =2.0:1
PROBABILITY OF ACCEPTANCE
100
80
60
40
20
10
.00 .50 1.00 1.50 2.00 2.50 3.00 θ0
.00 1.00 2.00 3.00 4.00 5.00 6.00 θ1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ0, θ1

CHART 20

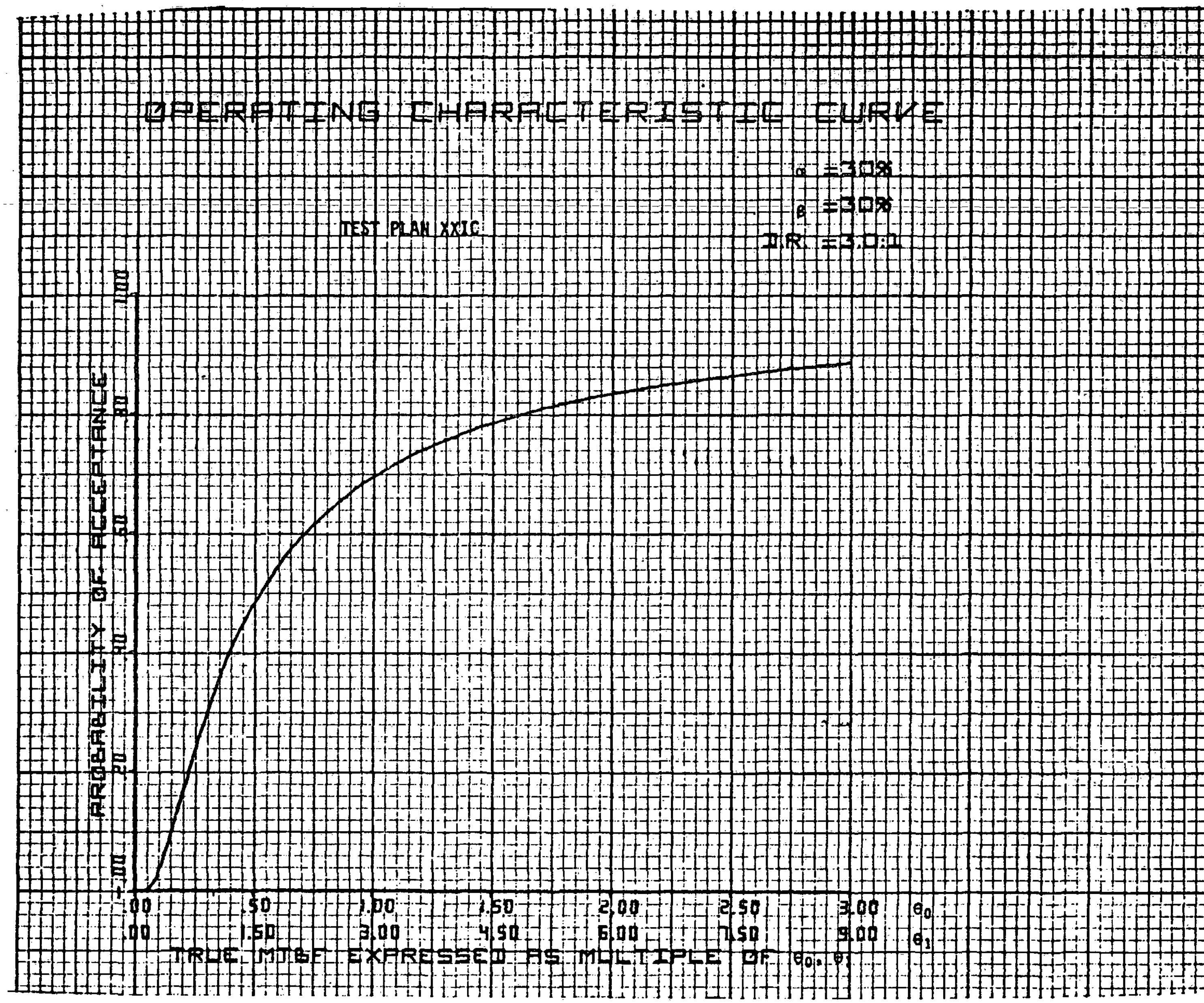

OPERATING CHARACTERISTIC CURVE
α =30%
β =30%
D.R. =3.0:1
TEST PLAN XXIC
PROBABILITY OF ACCEPTANCE
1.00
.80
.60
.40
.20
.00
.00
.50
1.00
1.50
2.00
2.50
3.00
θ0
.00
1.50
3.00
4.50
6.00
7.50
9.00
θ1
TRUE MTBF EXPRESSED AS MULTIPLE OF θ0, θ1

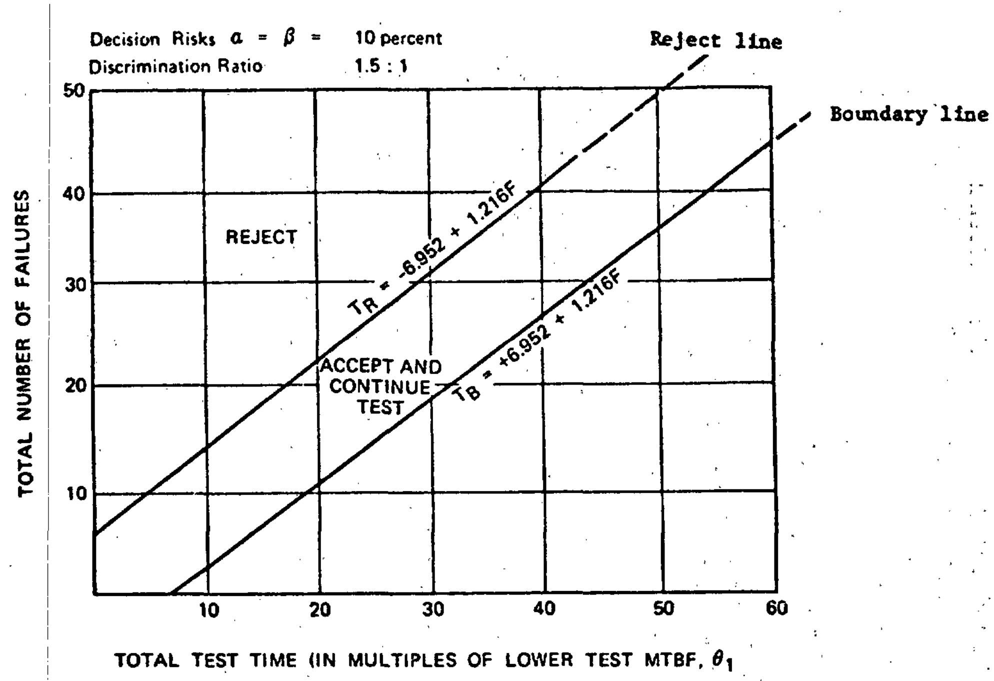
CHART 21

30.8 Alternative all equipment production reliability acceptance test plans. The following figures and charts present a set of all equipment production reliability acceptance test plans (two-line test plans) which may be used for production acceptance testing in lieu of Test Plan XVIIIC when it is desired to have a plan corresponding to some other PRST, if such other Test Plan was used during qualification. These are located in FIGURES C-10 through C-17 and Charts 22 through 29.

The accept and reject lines of the sequential tests do not follow the original Wald formulas. They have been modified to account for the effects on the test risks of truncation. In computing the all equipments test plans, this modification was not made and, hence, the accept and boundary lines of the all equipments test will not line up with the accept and reject lines of the corresponding sequential test. The difference is in the separation of the lines. It is felt the original Wald formulas are more appropriate for the all equipments plan. Otherwise each OC curve, representing a different test length, would require a different modification to the formulas.

30.9 Alternative fixed-length test plans. FIGURES C-18 through C-20 provide a complete set of fixed-length test plans for 10 percent consumer's risk (β), 20 percent β and 30 percent β, respectively, covering a range of test times from very short to quite long periods. To derive a fixed-length test plan from these figures, choose the consumer's risk (β) desired and turn to the appropriate figure (for example, FIGURE C-18 applied to 10 percent consumer's risk). Based on the test time available, select the test criteria which is applicable to the situation. As an example, a test plan with a consumer's risk of 10 percent and a total test time not to exceed 9.3 multiples of the lower test MTBF is desired. Turn to FIGURE C-18 and reading down the 4th column entitled TOTAL TEST TIME (T) X LOWER LOWER TEST MTBF (θ_1), find the test time closest to 9.3 but does not exceed it. In this case, the test time would be 9.27 multiples of θ_1. Reading across the row corresponding to 9.27 the test plan number is 10-6. This test plan will accept equipment if 5 or less failures occur during the 9.27 X θ_1 hours of testing. It will reject the equipment if 6 or more failures occur during that period. The row also defines the worst case (accept with 5 failures) acceptable observed MTBF ($\hat{\theta}$), for test plan 10-6 this value is 1.55 multiples of θ_1. The discrimination ratios corresponding to producer's risks of 10 percent, 20 percent, and 30 percent are also provided in the three right hand columns. Again, in the case of test plan 10-6 for a producer's risk of 30 percent, the discrimination ratio is 2.05:1. Similarly, for a producer's risk of 10 percent, the discrimination ratio is 2.94:1.

The procuring activity may select test plans from these tables, if it is felt that such a test plan is more appropriate than the standard plans of Section 4.4.

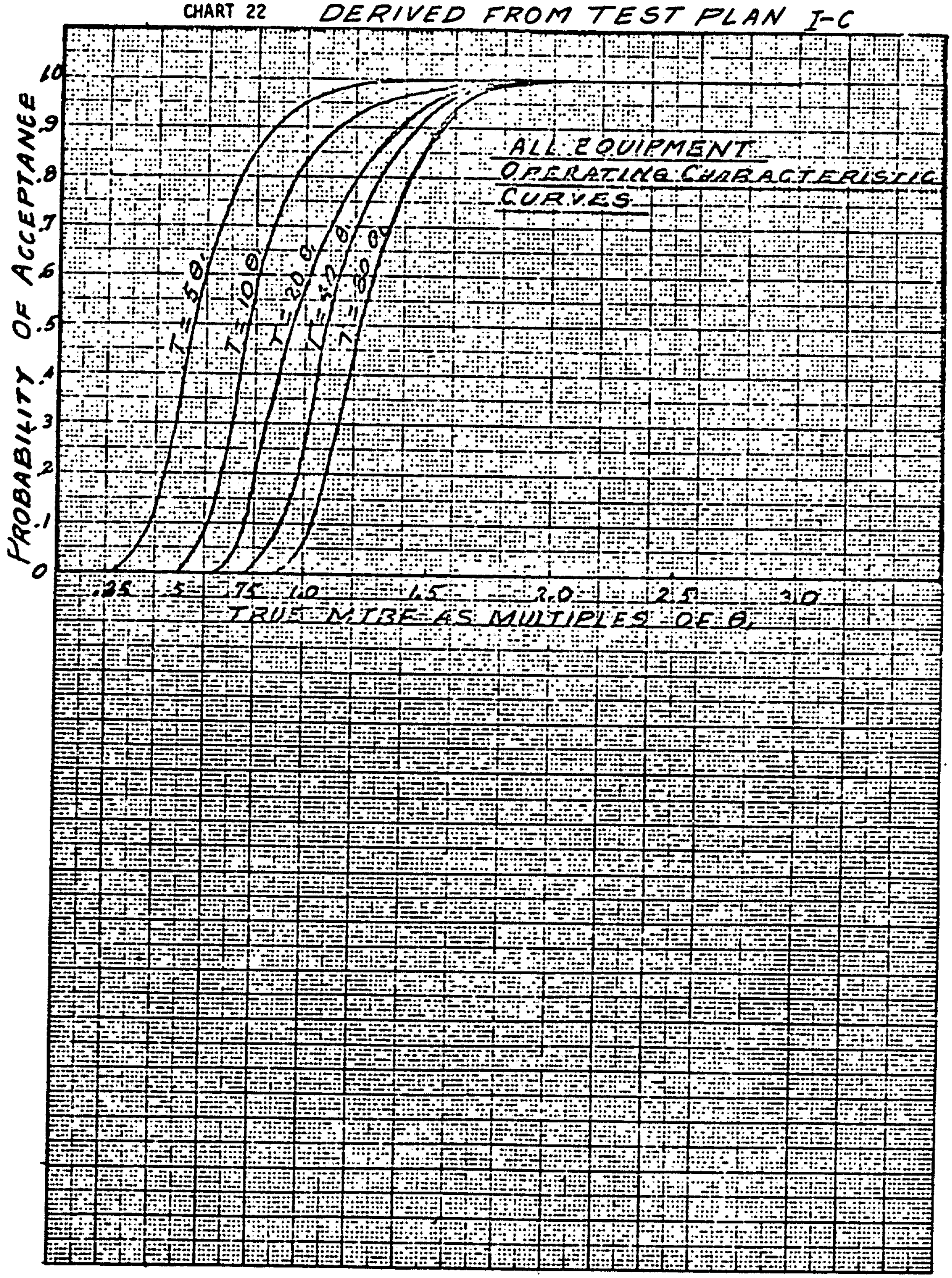


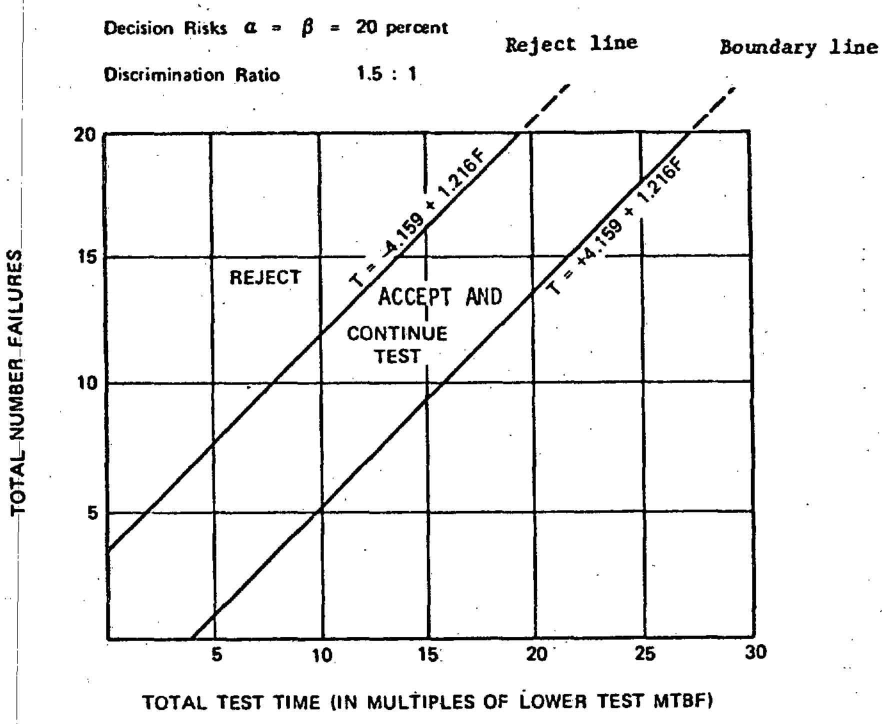
Number of Failures	Total Test Time* Reject (Equal or less)	Accept (Equal or more)	Number of Failures	Total Test Time* Reject (Equal or less)	Accept (Equal or more)
0	N/A	6.95	21	18.50	32.49
1	N/A	8.17	22	19.80	33.70
2	N/A	9.38	23	21.02	34.92
3	N/A	10.60	24	22.23	36.13
4	N/A	11.80	25	23.45	37.35
5	N/A	13.03	26	24.66	38.57
6	0.34	14.25	27	25.88	39.78
7	1.56	15.46	28	27.07	41.00
8	2.78	16.68	29	28.31	42.22
9	3.99	17.90	30	29.53	43.43
10	5.20	19.11	31	30.74	44.65
11	6.42	20.33	32	31.96	45.86
12	7.64	21.54	33	33.18	47.08
13	8.86	22.76	34	34.39	48.30
14	10.07	23.98	35	35.61	49.51
15	11.29	25.19	36	36.82	50.73
16	12.50	26.41	37	38.04	51.94
17	13.72	27.62	38	39.26	53.16
18	14.94	28.64	39	40.47	54.38
19	16.15	30.06	40	41.69	55.59
20	17.37	31.27	41	42.90	56.81

*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE C-10. Accept-Reject Criteria, derived from Test Plan IC

CHART 22 DERIVED FROM TEST PLAN I-C



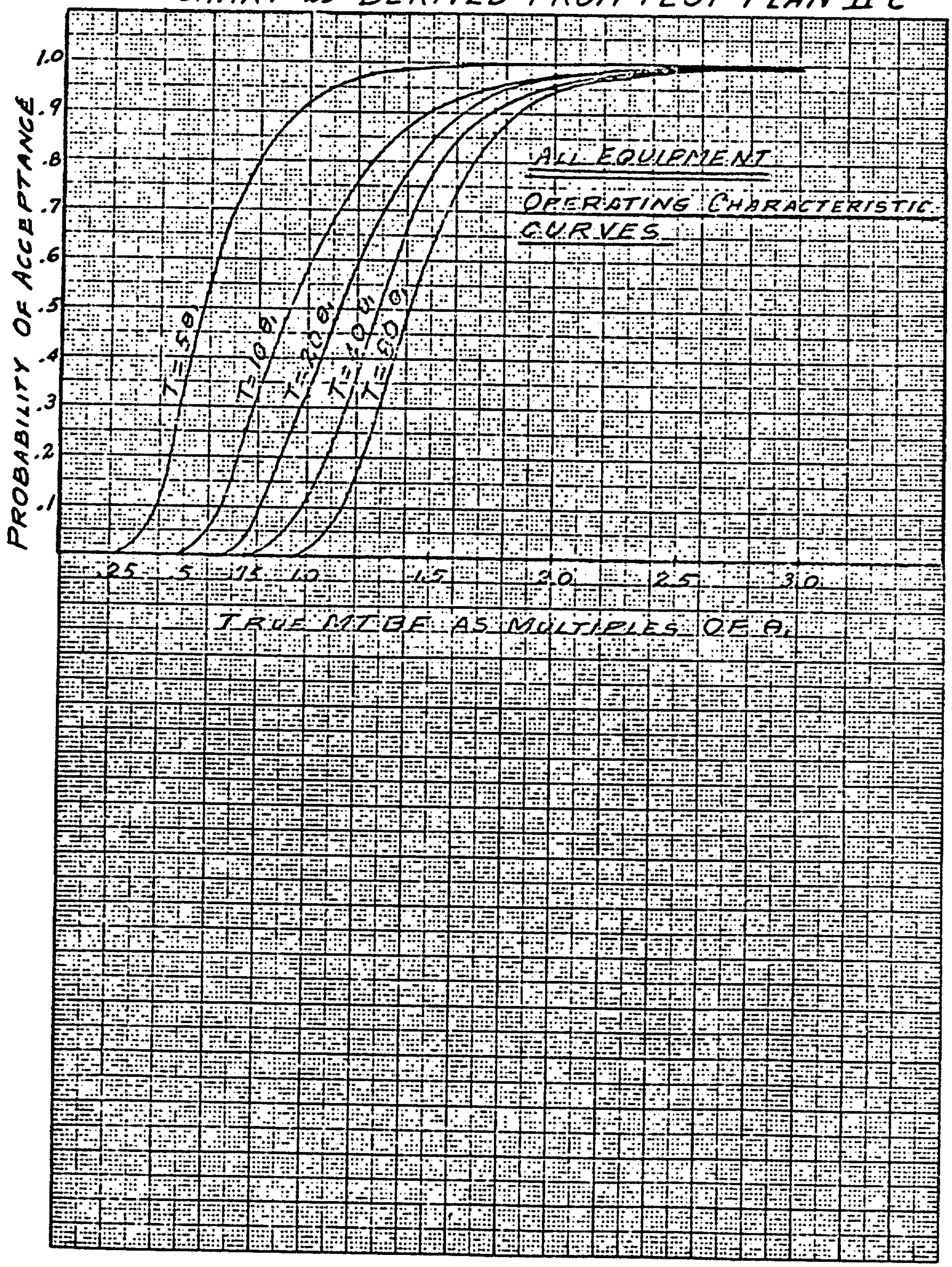


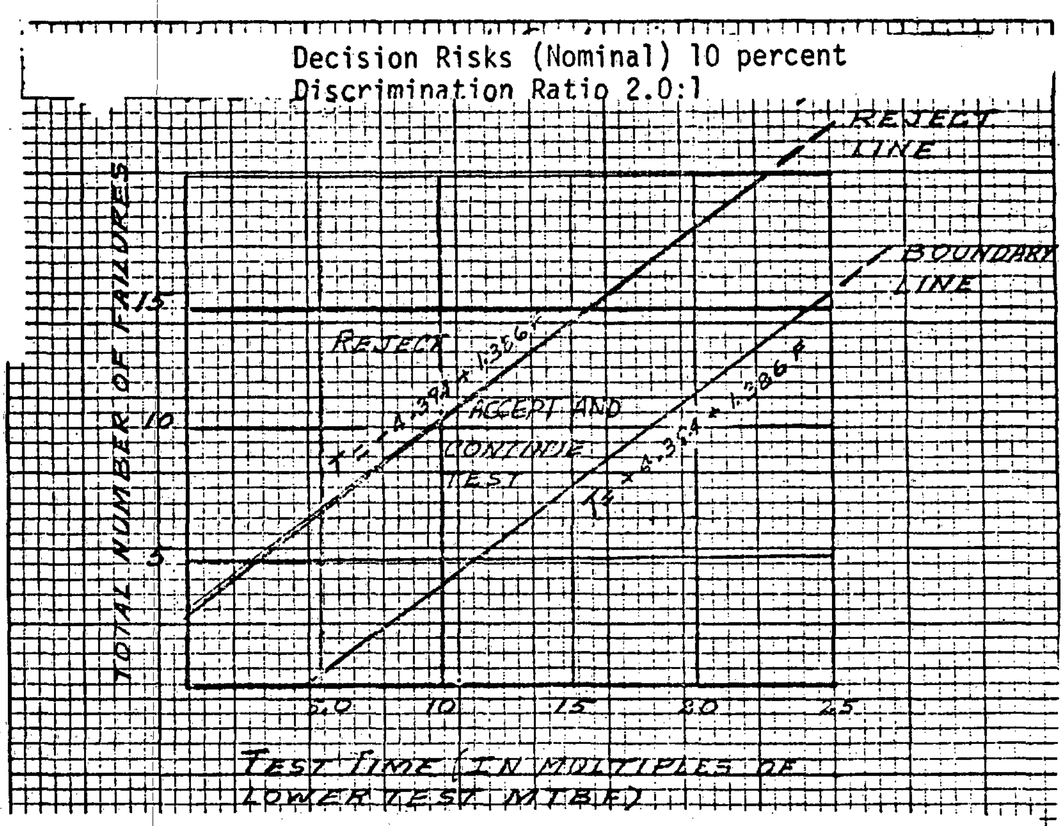
Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)	Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)
0	N/A	4.16	10	8.0	16.32
1	N/A	5.38	11	9.22	17.54
2	N/A	6.59	12	10.43	18.75
3	N/A	7.81	13	11.65	19.97
4	0.705	9.02	14	12.87	21.18
5	1.92	10.24	15	14.08	22.40
6	3.14	11.46	16	15.29	23.62
7	4.35	12.67	17	16.51	24.93
8	5.57	13.89	18	17.73	26.03
9	6.79	15.10	19	18.95	27.26

*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE C-11. Accept-reject criteria derived from Test Plan IIC.

CHART 23 DERIVED FROM TEST PLAN II C

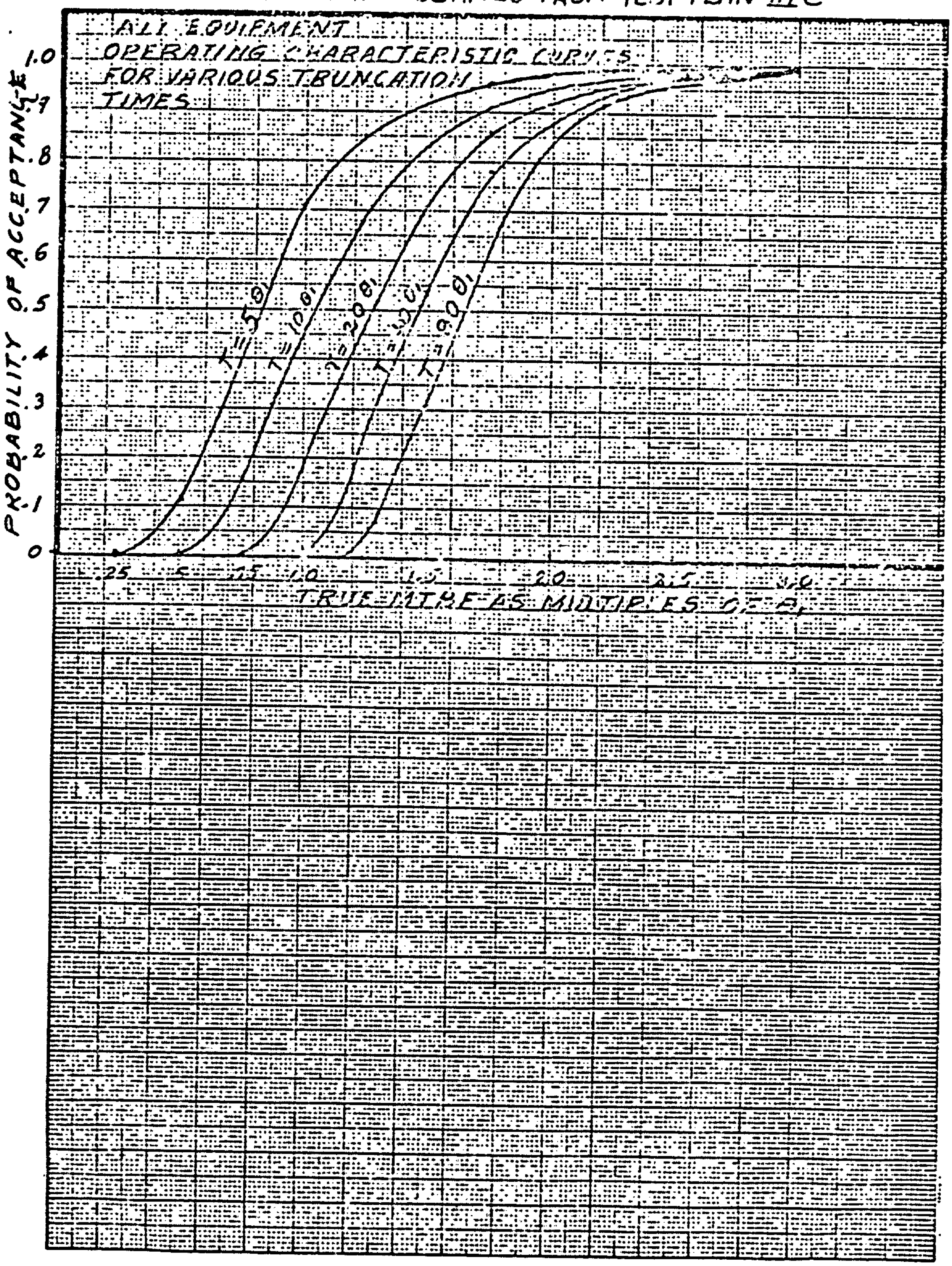




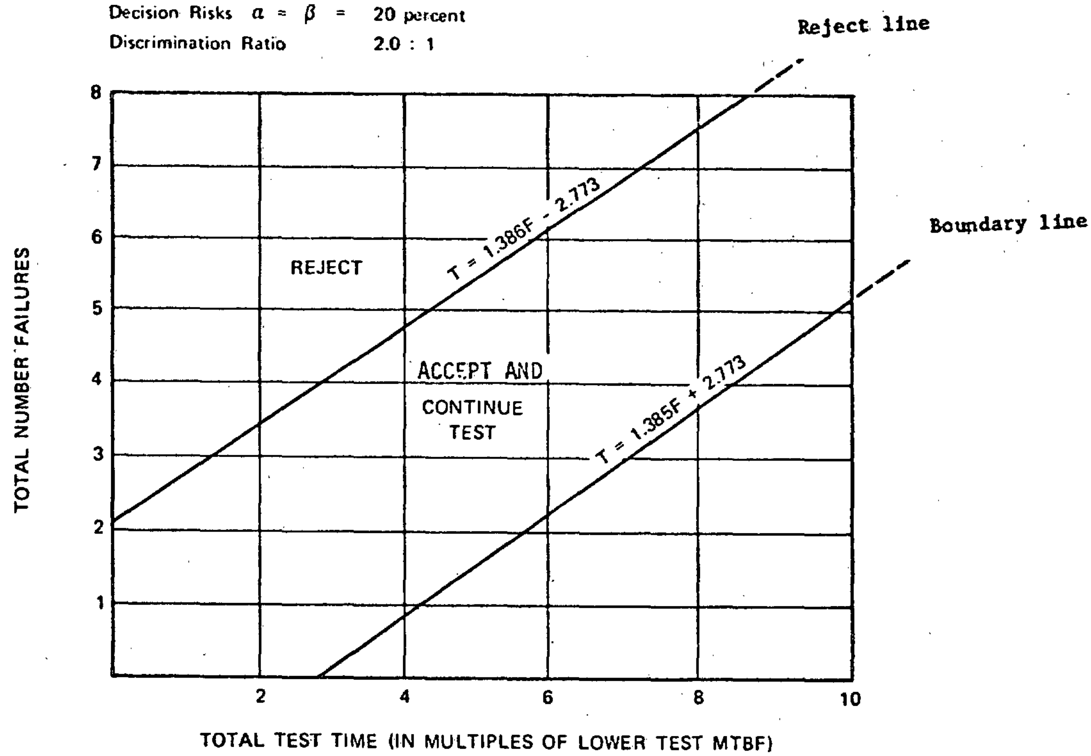
Number of failures	Total test time-reject equal or less	Boundary line-test time
0	N/A	4.39
1	N/A	5.78
2	N/A	7.166
3	N/A	8.55
4	1.15	9.938
5	2.536	11.324
6	3.922	12.71
7	5.308	14.096
8	6.69	15.48
9	8.08	16.86
10	9.47	18.25
11	10.85	19.64
12	12.24	21.03
13	13.63	22.4
14	15.01	23.79
15	16.39	25.18
16	17.78	26.57

FIGURE C-12. Accept-reject criteria, derived from test plan IIIC.

CHART 24 DERIVED FROM TEST PLAN IIIC



Decision Risks $\alpha = \beta =$ 20 percent
Discrimination Ratio 2.0 : 1

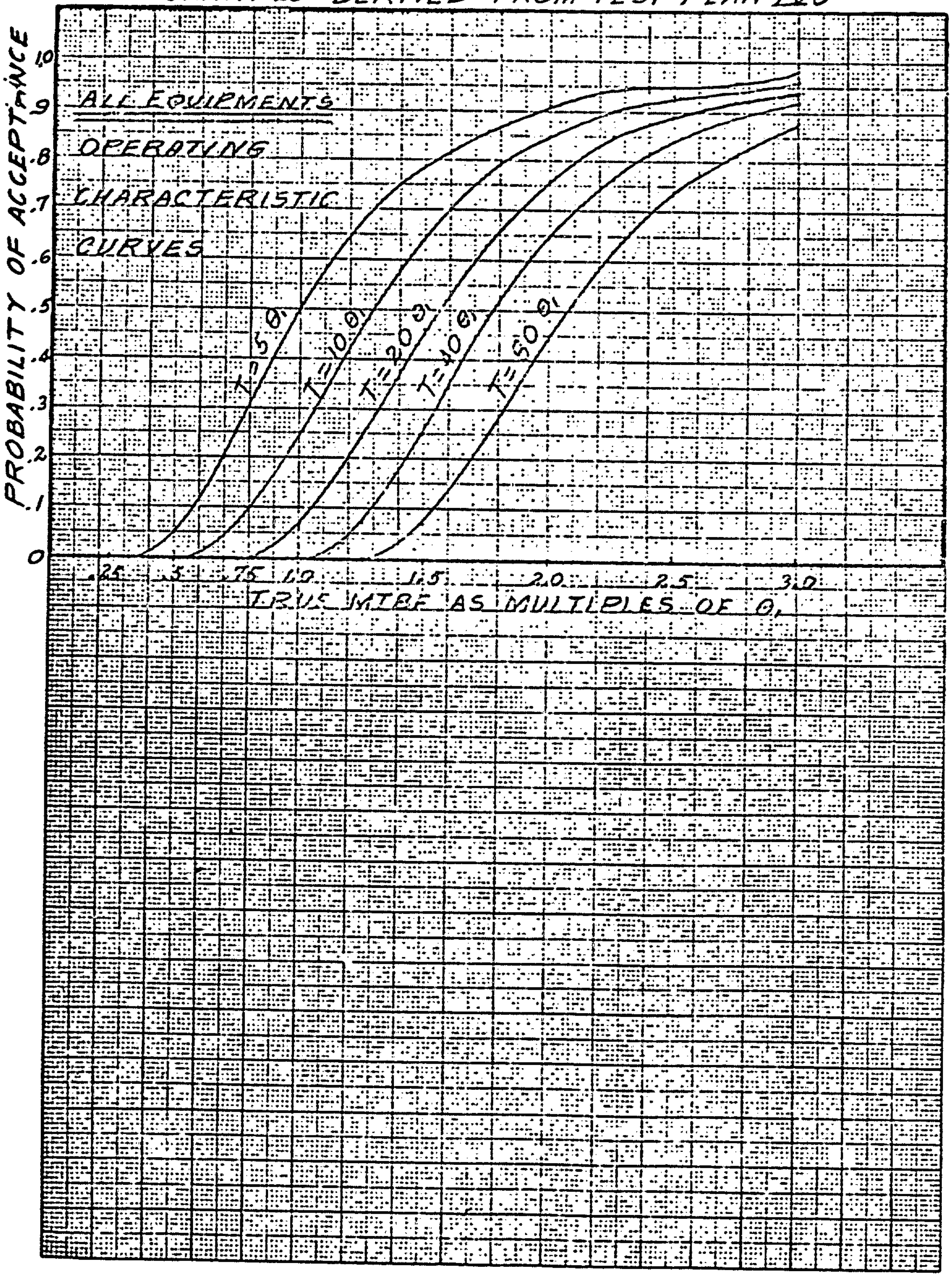


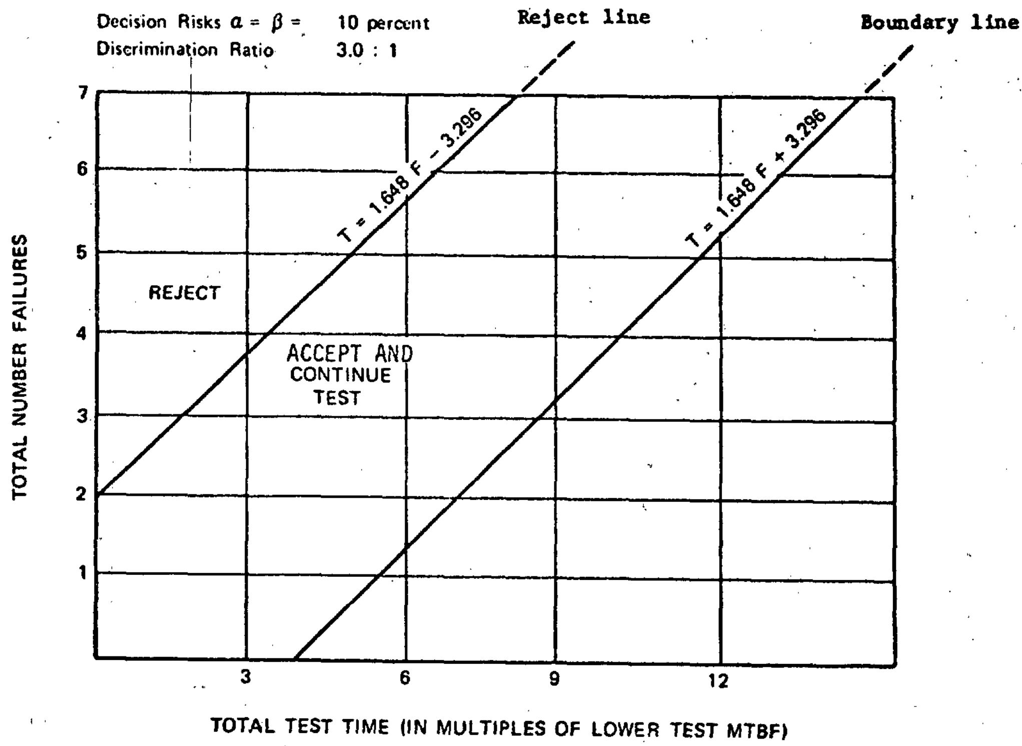
Number of Failures	Total Test Time* Reject (Equal or less)	Boundary Line
0	N/A	2.77
1	N/A	4.16
2	N/A	5.55
3	1.39	6.93
4	2.77	8.32
5	4.16	9.70
6	5.54	11.09
7	6.93	12.48
8	8.32	13.86

*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE C-13. Accept-reject criteria derived from Test Plan IVC.

CHART 25- DERIVED FROM TEST PLAN IVC





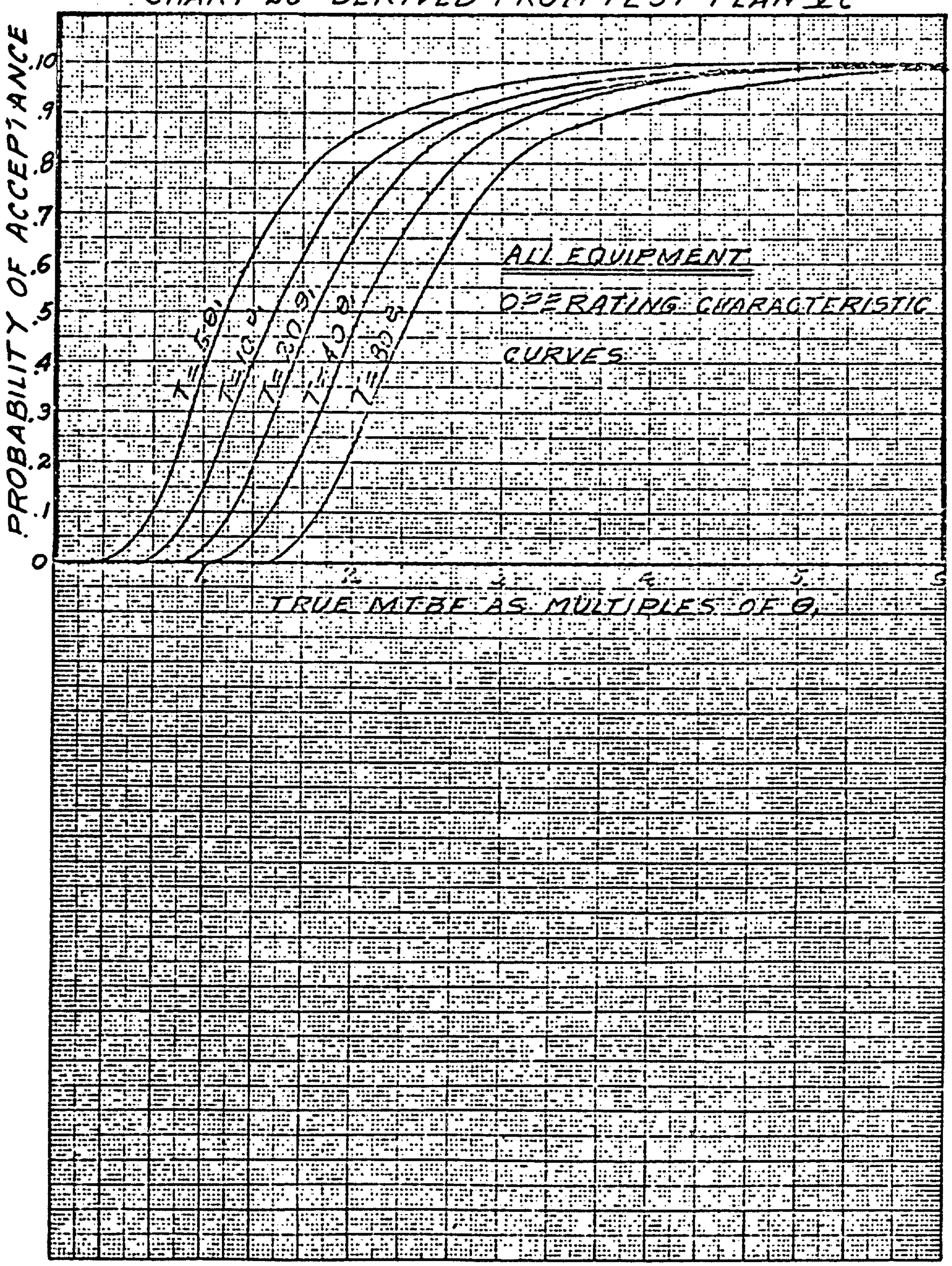
Total Test Time*

Number of Failures	Reject (Equal or less)	Boundary Line
0	N/A	3.30
1	N/A	4.94
2	0	6.59
3	1.65	8.24
4	3.30	9.87
5	4.94	11.54
6	6.59	13.18
7	8.24	14.83

*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

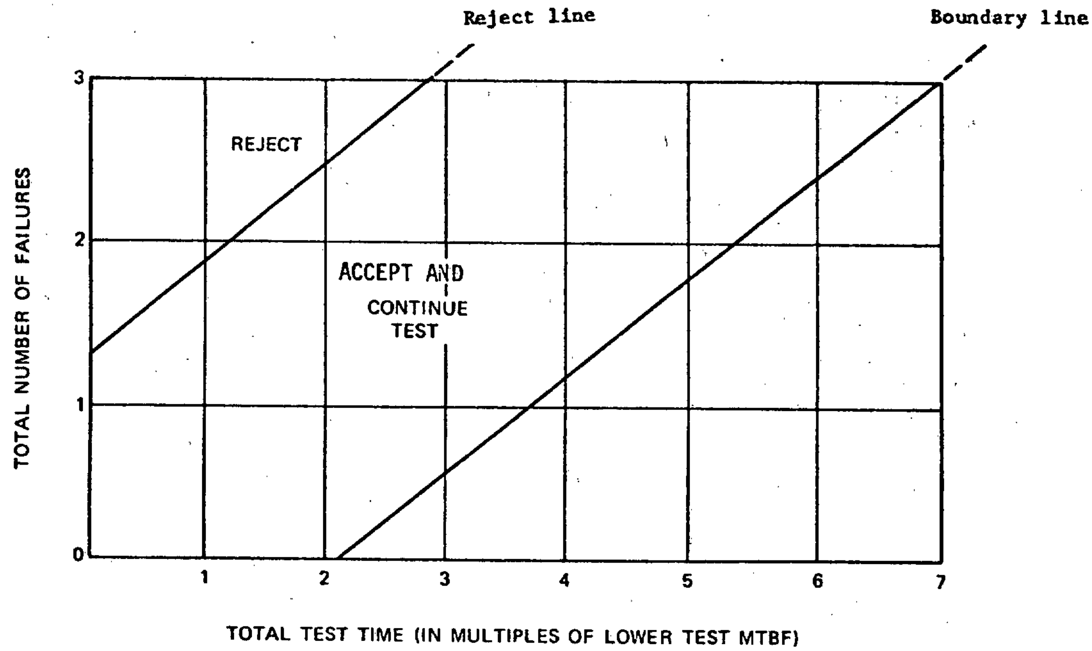
FIGURE C-14. Accept-reject criteria derived from Test Plan VC.

CHART 26 DERIVED FROM TEST PLAN XC



Decision Risks $\alpha = \beta =$ 20 percent

Discrimination Ratio 3.0 : 1



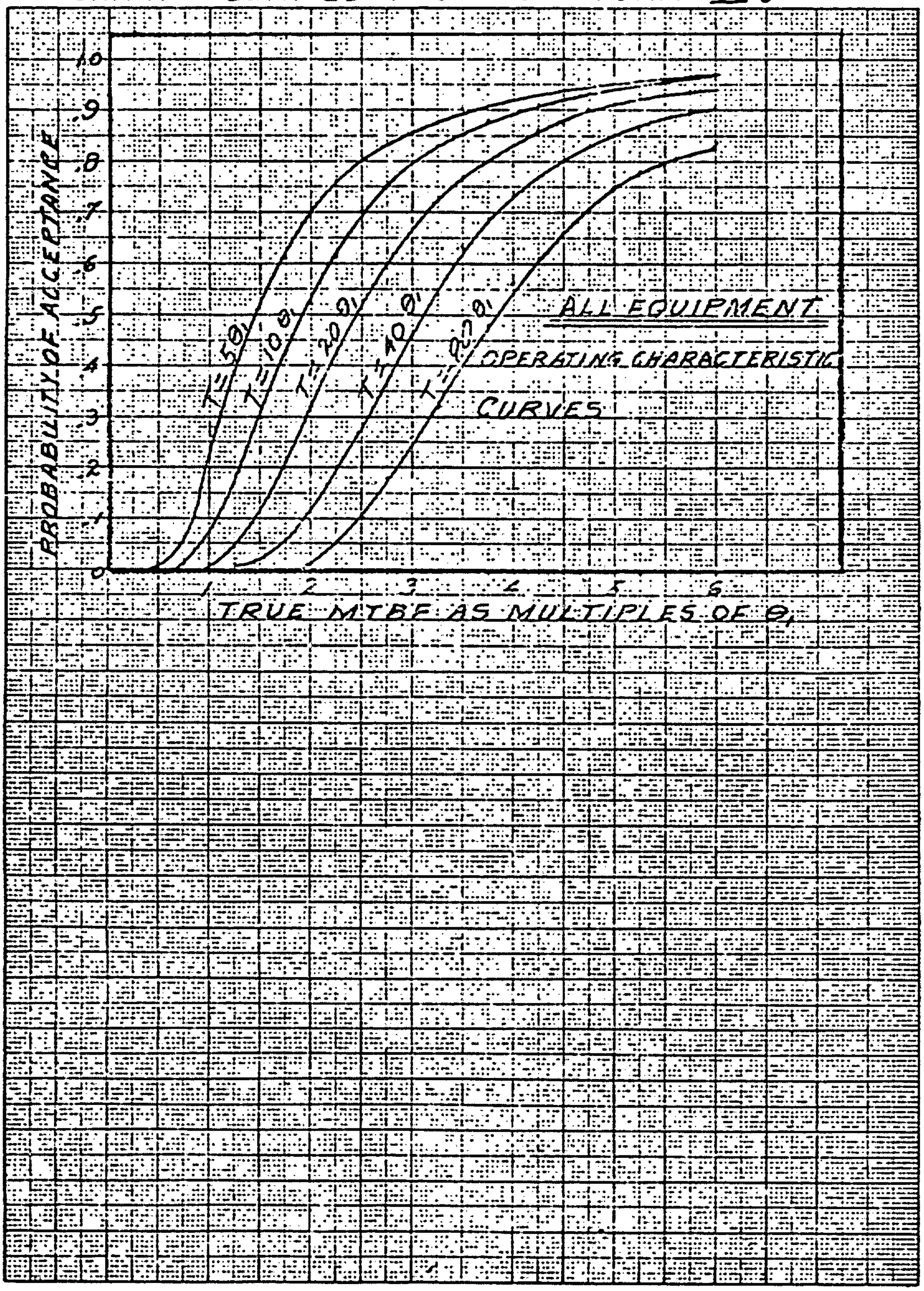
Total Test Time*

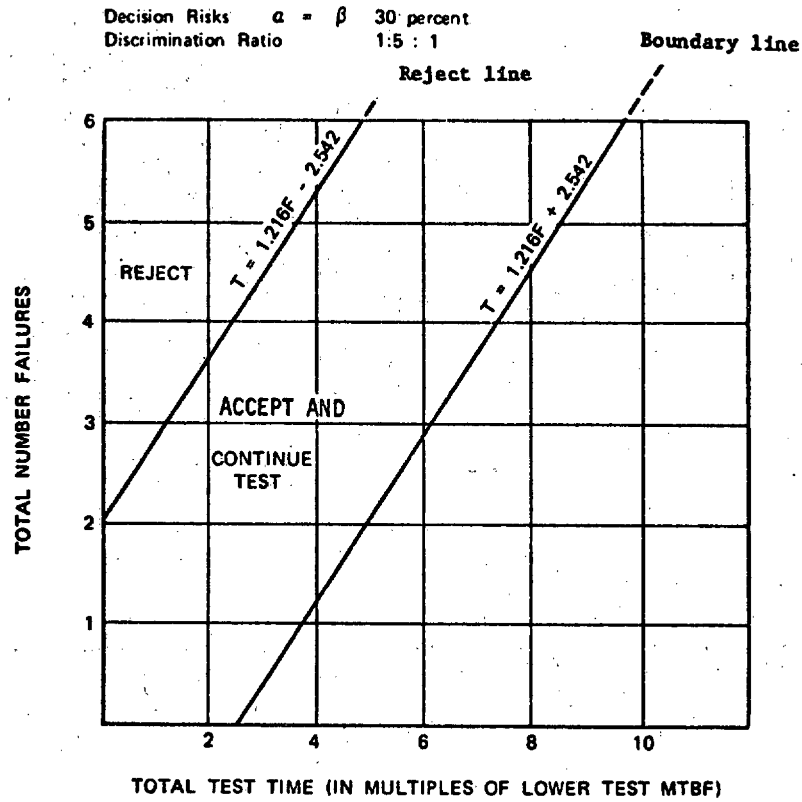
Number of Failures	Reject (Equal or less)	Boundary Line
0	N/A	2.08
1	N/A	3.73
2	1.22	5.38
3	2.87	7.02

*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE C-15. Accept-reject criteria derived from Test Plan VIC.

CHART 27 DERIVED FROM TEST PLAN VIC



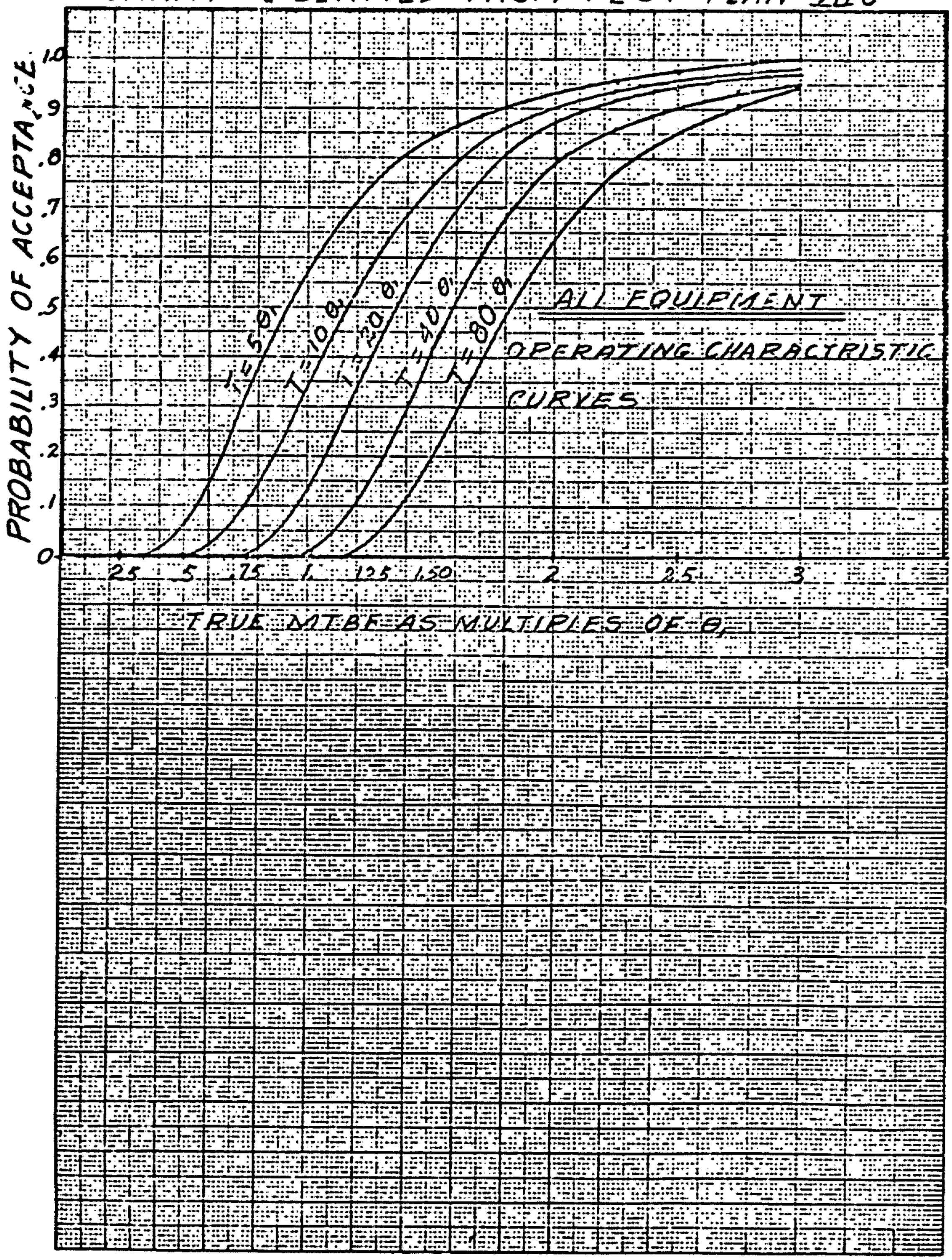


Number of Failures	Total Test Time* Reject (Equal or less)	Boundary Line
0	N/A	2.54
1	N/A	3.76
2	N/A	4.97
3	1.106	6.19
4	2.32	7.40
5	3.54	8.62
6	4.75	9.84

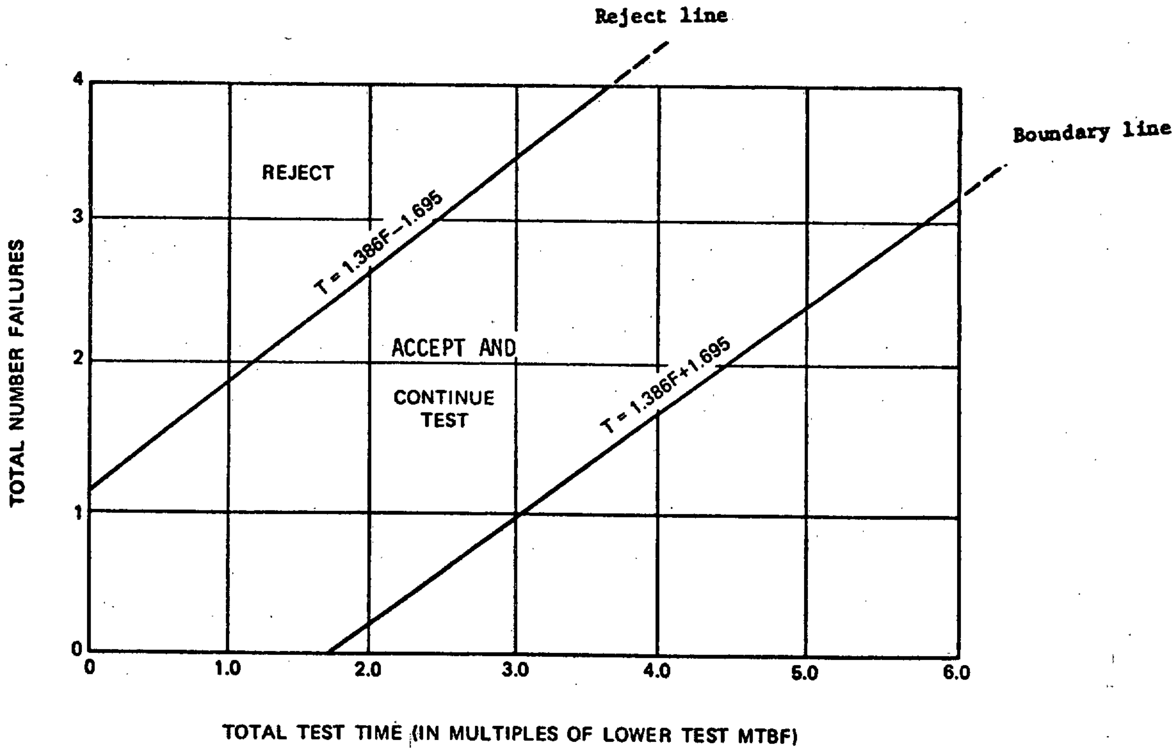
*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE C-16. Accept-reject criteria derived from Test Plan VIIC.

CHART 28 DERIVED FROM TEST PLAN VIIC



Decision Risks $\alpha = \beta =$ 30 percent
Discrimination Ratio 2.0 : 1



Total Test Time*

Number of Failures	Reject (Equal or less)	Boundary Line
0	N/A	1.70
1	N/A	3.08
2	1.077	4.47
3	2.46	5.85

*Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.4.1 for minimum test time per equipment.

FIGURE C-17. Accept-reject criteria derived from Test Plan VIIIC.

CHART 29 DERIVED FROM TEST PLAN VIIIC

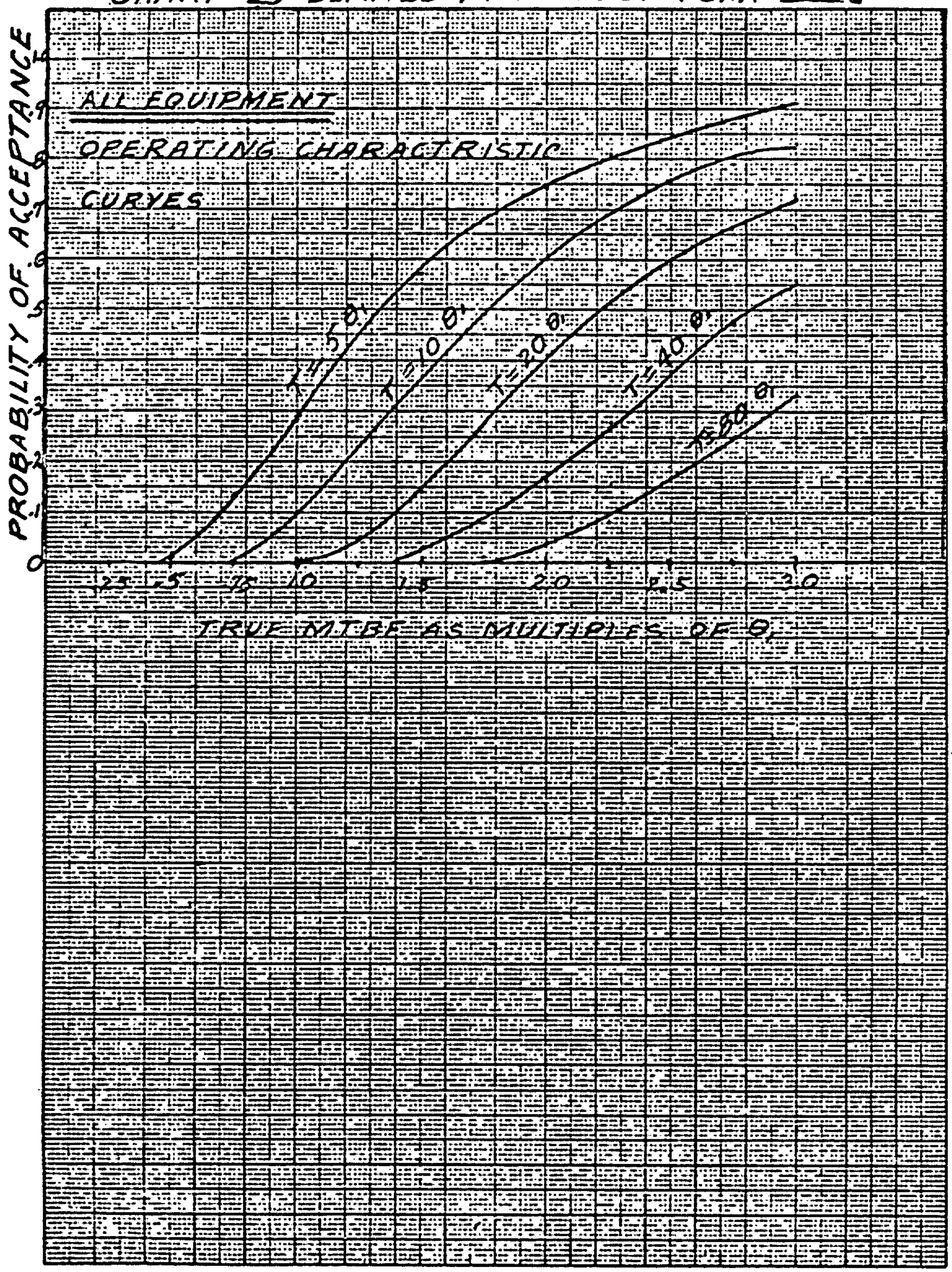
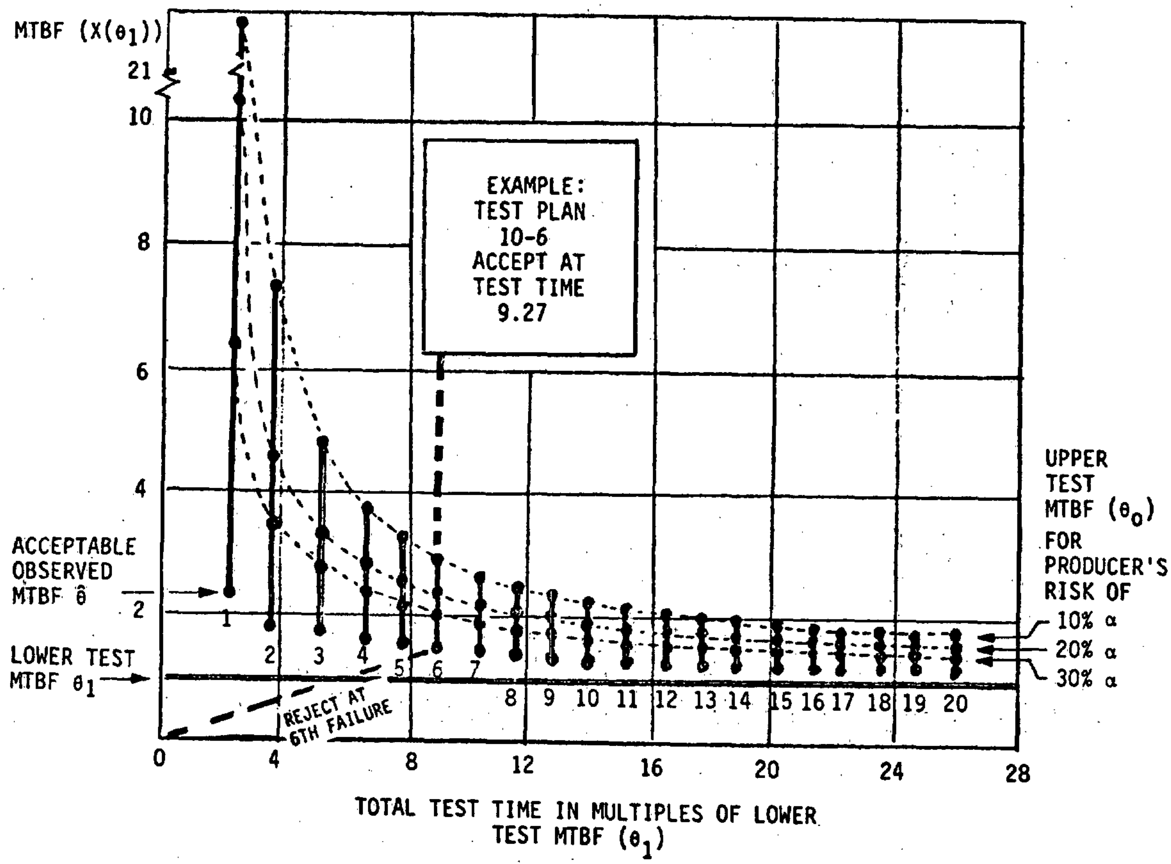


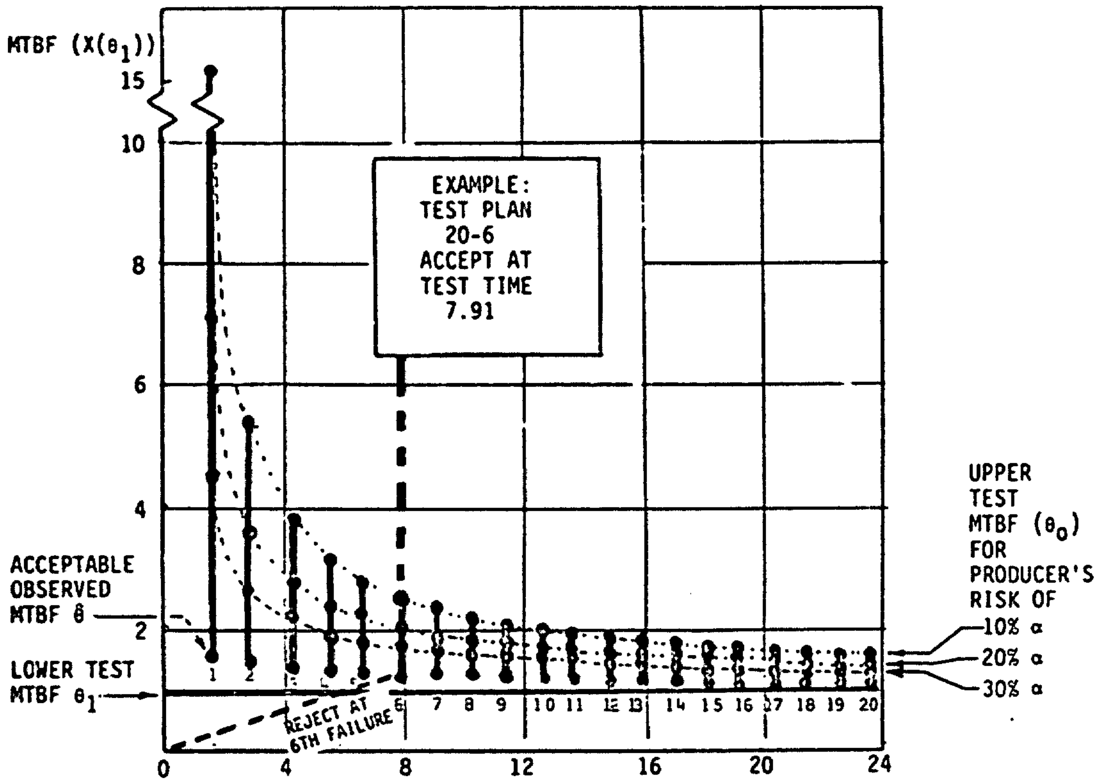
FIGURE C-18. 10% CONSUMER'S RISK (β) TEST PLANS



TEST PLAN NO'S	NO. FAILURES ACC.	REJ.	TOTAL TEST TIME(T) X LOWER TEST MTBF (θ_1)	ACCEPTABLE OBSERVED MTBF $\hat{\theta}$	UPPER TEST MTBF (θ_0) FOR PRODUCER'S RISK 30%	20%	10%
10-1	0	1	2.30	2.30+	6.46	10.32	21.85
10-2	1	2	3.89	1.94+	3.54	4.72	7.32
10-3	2	3	5.32	1.77+	2.78	3.47	4.83
10-4	3	4	6.68	1.67+	2.42	2.91	3.83
10-5	4	5	7.99	1.59+	2.20	2.59	3.29
10-6	5	6	9.27	1.55+	2.05	2.38	2.94
10-7	6	7	10.53	1.50+	1.95	2.22	2.70
10-8	7	8	11.77	1.47+	1.86	2.11	2.53
10-9	8	9	12.99	1.43+	1.80	2.02	2.39
10-10	9	10	14.21	1.42+	1.75	1.95	2.28
10-11	10	11	15.41	1.40+	1.70	1.89	2.19
10-12	11	12	16.60	1.38+	1.66	1.84	2.12
10-13	12	13	17.78	1.37+	1.63	1.79	2.06
10-14	13	14	18.96	1.35+	1.60	1.75	2.00
10-15	14	15	20.13	1.34+	1.58	1.72	1.95
10-16	15	16	21.29	1.33+	1.56	1.69	1.91
10-17	16	17	22.45	1.32+	1.54	1.67	1.87
10-18	17	18	23.61	1.31+	1.52	1.62	1.84
10-19	18	19	24.75	1.30+	1.50	1.62	1.81
10-20	19	20	25.90	1.29+	1.48	1.60	1.78

FIGURE C-18. 10 percent consumer's risk (β) test plans.

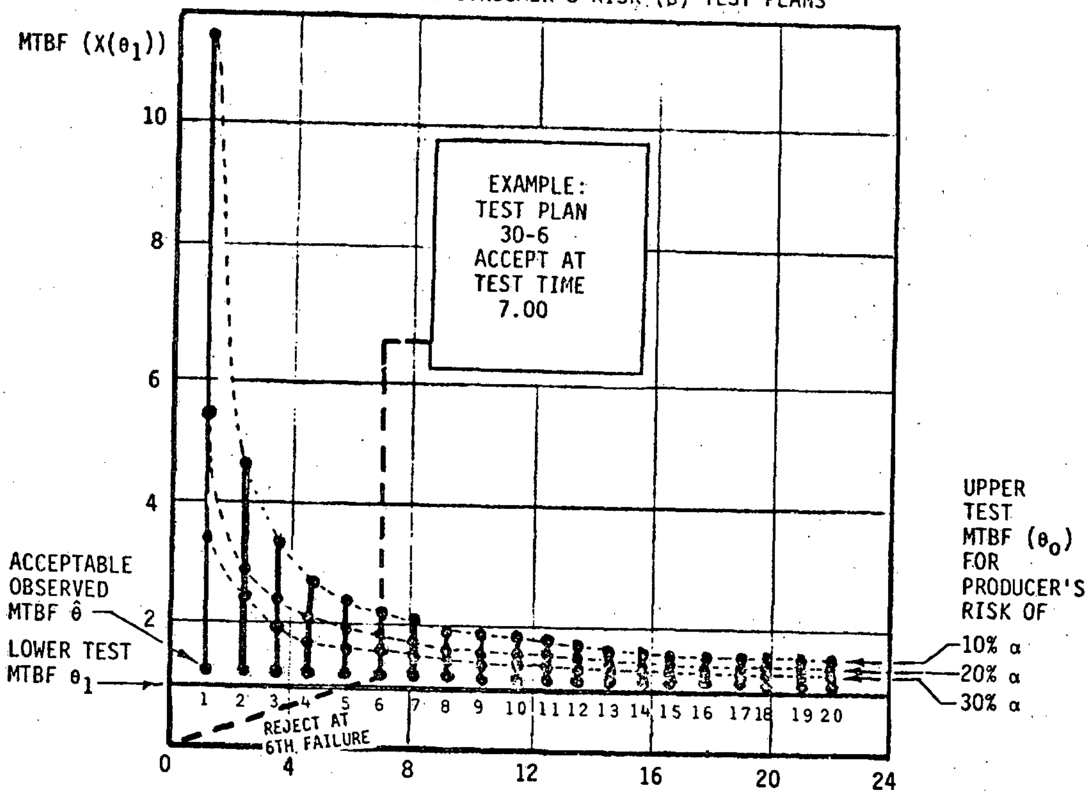
FIGURE C-19. 20% CONSUMER'S RISK (β) TEST PLANS



TEST PLAN NO's	NO. FAILURES ACC.	REJ.	TOTAL TEST TIME(T) X LOWER TEST MTBF (θ_1)	ACCEPTABLE OBSERVED MTBF $\hat{\theta}$	UPPER TEST MTBF (θ_0) FOR PRODUCER'S RISK 30%	20%	10%
20-1	0	1	1.61	1.61+	4.51	7.22	15.26
20-2	1	2	2.99	1.50+	2.73	3.63	5.63
20-3	2	3	4.28	1.43+	2.24	2.79	3.88
20-4	3	4	5.51	1.38+	1.99	2.40	3.16
20-5	4	5	6.72	1.34+	1.85	2.17	2.76
20-6	5	6	7.91	1.32+	1.75	2.03	2.51
20-7	6	7	9.07	1.30+	1.68	1.92	2.33
20-8	7	8	10.23	1.28+	1.62	1.83	2.20
20-9	8	9	11.38	1.26+	1.57	1.77	2.09
20-10	9	10	12.52	1.25+	1.54	1.72	2.01
20-11	10	11	13.65	1.24+	1.51	1.67	1.94
20-12	11	12	14.78	1.23+	1.48	1.64	1.89
20-13	12	13	15.90	1.22+	1.46	1.60	1.84
20-14	13	14	17.01	1.21+	1.44	1.58	1.80
20-15	14	15	18.12	1.21+	1.42	1.55	1.76
20-16	15	16	19.23	1.20+	1.40	1.53	1.73
20-17	16	17	20.34	1.19+	1.39	1.51	1.70
20-18	17	18	21.44	1.19+	1.38	1.49	1.67
20-19	18	19	22.54	1.18+	1.37	1.48	1.65
20-20	19	20	23.63	1.18+	1.35	1.46	1.63

FIGURE C-19. 20 percent consumer's risk (β) test plans.

FIGURE C-20. 30% CONSUMER'S RISK (β) TEST PLANS



TEST PLAN NO'S	NO. FAILURES ACC.	NO. FAILURES REJ.	TOTAL TEST TIME(T) X LOWER TEST MTBF (θ_1)	ACCEPTABLE OBSERVED MTBF $\hat{\theta}$	UPPER TEST MTBF (θ_0) FOR PRODUCER'S RISK 30%	20%	10%
30-1	0	1	1.20	1.20+	3.37	5.39	11.43
30-2	1	2	2.44	1.22+	2.22	2.96	4.59
30-3	2	3	3.62	1.20+	1.89	2.35	3.28
30-4	3	4	4.76	1.19+	1.72	2.07	2.73
30-5	4	5	5.89	1.18+	1.62	1.91	2.43
30-6	5	6	7.00	1.17+	1.55	1.79	2.22
30-7	6	7	8.11	1.16+	1.50	1.71	2.08
30-8	7	8	9.21	1.15+	1.46	1.65	1.98
30-9	8	9	10.30	1.14+	1.43	1.60	1.90
30-10	9	10	11.39	1.14+	1.40	1.56	1.83
30-11	10	11	12.47	1.13+	1.38	1.53	1.78
30-12	11	12	13.55	1.13+	1.36	1.50	1.73
30-13	12	13	14.62	1.12+	1.34	1.48	1.69
30-14	13	14	15.69	1.12+	1.33	1.45	1.66
30-15	14	15	16.76	1.12+	1.31	1.43	1.63
30-16	15	16	17.83	1.11+	1.30	1.42	1.60
30-17	16	17	18.90	1.11+	1.29	1.40	1.58
30-18	17	18	19.96	1.11+	1.28	1.39	1.56
30-19	18	19	21.02	1.11+	1.27	1.38	1.54
30-20	19	20	22.08	1.10+	1.27	1.36	1.52

FIGURE C-20. 30 percent consumer's risk (β) test plans.

APPENDIX E

TEST INSTRUMENTATION AND FACILITIES

10. GENERAL

10.1 Scope. This appendix sets forth minimum requirements for test equipment and facilities for the performance of reliability qualification and production acceptance tests.

10.2 Purpose. The purpose of this appendix is to assure that adequate planning is accomplished and that appropriate and sufficient equipment and facilities have been provided, with necessary certifications and calibrations, acceptable to the procuring activity, prior to the commencement of reliability qualification and production acceptance tests.

20. TEST FACILITIES AND APPARATUS

Test facilities, chambers, and apparatus used in conducting the tests of MIL-STD-781 shall be capable of meeting the conditions required. The range of these conditions are presented in Appendix B.

20.1 Test chambers. Test chambers shall be capable of maintaining the environmental conditions of the specified test level. The chamber shall be capable of:

a. Maintaining the ambient and forced air temperatures at the specified temperature level ±2°C during the test. The rate of temperature change of the thermal medium in both heating and cooling cycles shall average not less than 5°C/minute. Chamber and equipment cooling air temperatures shall be monitored continuously, or periodically, at a monitoring frequency sufficient to ensure proper chamber operation. Means shall be provided to interrupt the programming used in the automatic control of temperature cycling until maximum and minimum air temperature requirements are satisfied. Protective devices shall be installed to shut off both the equipment being tested, and the heating source in case of temperature overruns. However, if equipment has forced cooling, this flow should be maintained to prevent overheating of equipment under test
b. Maintaining specified vibration within plus or minus 10 percent for sinusoidal sweep or single frequency and as follows for random vibration (see the Random Vibration Test paragraph of Method 514.2, MIL-STD-810)

Power spectral density of test control signal shall not deviate from specified requirements by more than

+100, -30 percent (+3, -1.5 dB) below 500
+100, -50 percent (±3 dB) between 500 to 2000 Hz

except deviations as large as +300, -75 percent (±6 dB) shall be allowed over cumulative bandwidth of 100 Hz maximum between 500 and 2000 Hz.

It is recommended that the vibration equipment be checked for proper operation each 24 hours of operation, and that vibration be monitored with automatic devices to prevent over-test conditions.

20.2 Equipment cooling. It is intended that the equipment be cooled by means of its designed-in cooling system. When it is not practical to test the equipment and its operational cooling system as a unit, the simulated coolant conditions and attributes used shall be approved by the procuring activity (as part of test procedures). The simulated cooling conditions and attributes shall be developed using the procedures of 4.3.1. Regardless of the method of cooling, all equipments being tested shall be subjected to the conditions of mission/environmental profile which are contractually specified. The coolant attributes shall be as follows:

20.2.1 External coolant method. When there is minor or no mixing between the chamber medium and the coolant (such as ducted liquid, ducted gas, or direct blast gas methods), the coolant shall:

a. Be the type used operationally
b. Be at the maximum temperature and the minimum rate of flow (per coolant input requirements in tested equipment specifications) when the chamber temperature is at the highest, and
c. Be at the minimum temperature and the maximum rate of flow when the chamber temperature is at its lowest. When the chamber temperature is below the specified lower limit temperature for cooling air, and the equipment is turned off, the cooling air supply shall correspond to conditions anticipated in the equipment installation

20.2.2 Internal coolant method. When the gas within the chamber is used as the coolant, it shall:

a. Be at a temperature in accordance with the required test level in the approved test procedure
b. Be at the minimum rate of flow (per coolant input requirements in tested equipment specification) at the highest chamber temperature, and
c. Be at the maximum rate of flow at the lowest chamber temperature

20.3 Test instrumentation. Test instrumentation, beyond that required for the environmental chambers, must be provided to measure and monitor the performance parameters of the equipment under test, as listed in the test procedures.

20.4 Calibration/accuracy. Both the environmental and monitoring test facilities shall be determined to be in proper operating condition as specified in MIL-C-45662. All instruments and test instrumentation used in conducting the tests specified in MIL-STD-781 shall have an accuracy greater than the tolerance for the variable to be measured.

20.5 Testing the test facility. Operate the test facility to determine that the test setup operates properly under the required test conditions. Equipment other than the test samples shall be used to verify proper operation of the test setup unless otherwise approved by the procuring activity.

20.6 Installation of test item in test facility. Unless otherwise specified, the test item shall be installed in the test facility in a manner that will simulate service usage, making connections and attaching instrumentation as necessary. Plugs, covers, and inspection plates not used in operation, but used in servicing shall remain in place. When mechanical or electrical connections are not used, the connections normally protected in service shall be adequately covered. For tests where temperature values are controlled, the test chamber shall be at standard ambient conditions when the test item is installed. The test item shall then be operated to determine that no malfunction or damage was caused due to faulty installation or handling.

APPENDIX F

NOTES ON DATA REQUIREMENTS

10. GENERAL

10.1 Scope. This appendix provides notes for the guidance of the procuring activity in generating the detail equipment specification and the contractual data requirements.

10.2 Costs. Data requirements should be placed on contract only when review of the data by the procuring activity at the contractor's facility is not cost effective. When data requirements are included in the DD Form 1423, Contract Data Requirements List, the contractor's format should be used unless there are considerable cost savings to the procuring activity through the use of a specified format.

10.3 Contractual responsibility considerations. The detailed test procedures for demonstrating a contractual reliability requirement are used to show contractual compliance and, therefore, must receive the concurrence of the procuring activity. Otherwise, the reliability requirements of the contract could be compromised without the knowledge of the procuring activity. Great care should be exercised in placing on contract the tasks which will generate the information required by many of the data item descriptions. The procuring activity must avoid telling the contractor how to accomplish the task of attaining the required reliability and approving the design method he uses. For if the contractor does all that he states he will do, and still fails the reliability test, and the procuring activity has given formal approval of the design tasks and the manner in which they were executed, then the procuring activity will have jeopardized its contractual position. Then the only recourse may be to fund correction of the deficiency or to accept the less-than-required results. As long as the procuring activity confines itself to performance requirements, including reliability, and does not dictate the design method for accomplishing these requirements, the procuring activity is on firm contractual grounds.

20. ORDERING DATA

The user of this military standard should consider specific requirements for the following items, and include in the approprate contractual documents, as well as specifying the specific military standards to be used by title, number and dates.

a. Equipment application and its mission profile. Note: In lieu of a suitable mission profile, the procuring activity should incorporate the following items as deliverables in the contract to enable the contractor to develop the mission/environmental profiles
   1. Environmental Development Plan (EDP)
   2. Environmental Profile Report (EPR)
   3. Environmental Design criteria Document (EDCD) as described in Section 4 of MIL-STD-1670 (AS)
b. Minimum test levels (if not readily obtainable from a.)
c. Maximum duty cycle of the equipment and equipment life desired
d. Equipment/system upper test MTBF(θ_0) and the lower limit unacceptable MTBF (θ_1)
e. Standard Test Plan to be used (Section 4.4 of this standard)
f. The equipment operating parameters to be measured and the frequency of measurement
g. Specific definition(s) of failure for the equipment involved and instructions concerning the replacement of deteriorated (but not failed) parts
h. Confidence interval to be used in estimating true MTBF demonstrated during the test (θ)
i. Specific definitions for failure scoring in reliability calculations that ensure consistency between laboratory and field results. Scoring should consider:
   1. Failure free reference run prior to test to establish performance benchmarks
   2. Parts removed in error

3. Failures occurring during fault isolation and repair actions
4. Failures occurring during environmental checkout following repair
(The above will reduce likelihood of definitional differences between demonstrated and field MTBFs. Establish clear understanding of ground rules used to determine compliance with contractual reliability requirements).

j. *Preconditioning burn-in test time and conditions.*
k. Lot definition and sample size, if reliability acceptance sampling tests are used
l. Government furnished equipment list
m. Contractor test plan requirement
n. Test procedures requirement
o. Action in case of failure during reliability test
p. Corrective action approval
q. Preventive maintenance to be allowed during reliability tests
r. Supporting documents, with data and analysis
s. Test report requirements
t. Instructions for disposition of equipment under test at completion of test

30. DATA ITEM DESCRIPTIONS

The following listings of DIDS provides the source of possible data item descriptions and reporting formats that implementation of MIL-STD-781C should require.

Paragraph	Data Requirement	Applicable DID
5.1.2	PLAN, RELIABILITY TEST	DI-R-7033
5.1.3	PROCEDURES, RELIABILITY TESTS	DI-R-7035
5.1.5	REPORT, THERMAL SURVEY	DI-R-7036
5.1.6	REPORT, VIBRATION SURVEY	DI-R-7037
5.1.9	REPORT, BURN-IN TEST	DI-R-7040
5.9	PLAN, CORRECTIVE ACTION	DI-R-7038
5.13.1	REPORTS, RELIABILITY TEST AND DEMONSTRATION	DI-R-7034
5.13.2.1	REPORT, FAILED ITEM ANALYSIS	DI-R-7039
5.13.2.1	REPORT, FAILURE SUMMARY AND ANALYSIS	DI-R-7041

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b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

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