MIL-STD-471A
27 March 1973
Superseding
MIL-STD-471
15 Feb 1966 and
MIL-STD-473
3 May 1971

MILITARY STANDARD

MAINTAINABILITY VERIFICATION/DEMONSTRATION/EVALUATION

MISC-0855

DEPARTMENT OF DEFENSE
WASHINGTON DC

MAINTAINABILITY VERIFICATION/DEMONSTRATION/EVALUATION

MIL-STD-471A

1. This standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be reported to the preparing activity (see Defense Standardization Directory SD-1 for mailing address).

FOREWORD

Maintainability, a characteristic of design and installation and affected by various personnel and logistic factors, is one of many system requirements which must be considered during the system engineering effort, The degree of maintainability achieved depends upon the requirements imposed and management emphasis on maintainability. This standard defines a carefully planned program to be implemented for verification, demonstration and evaluation of maintainability.

The purpose of this standard is to establish uniform procedures, test methods, and requirements for verification, demonstration, and evaluation of the achievement of specified maintainability requirements and for assessment of the impact of planned logistic support.

This standard is applicable to all Department of Defense procurements which require a maintainability verification/demonstration/evaluation of maintainability requirements.

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1. SCOPE

1.1 Purpose. This standard provides procedures and test methods for verification, demonstration, and evaluation of qualitative and quantitative maintainability requirements. It also provides for qualitative assessment of various integrated logistic support factors related to and impacting the achievement of maintainability parameters and item downtime, e.g., technical manuals, personnel, tools and test equipment, maintenance concepts and provisioning.

1.2 Application. The standard is intended for use when verification, demonstration, and evaluation of maintainability requirements for hardware procurements is required. The verification, demonstration, and evaluation of achievement of maintainability requirements shall normally be conducted in three (3) phases, as described in Section 4, and in conjunction with verification, demonstration, and evaluation of the requirements for total Integrated Logistic Support. Exceptions to the three phases shall be as specified by the procuring activity.

2. APPLICABLE DOCUMENTS

The issues of the following documents in effect on the date of invitation for bids or request for proposal form a part of this standard to the extent specified herein:

STANDARDS

MILITARY

MIL-STD-280	Definitions of Item Levels, Item Exchangeability, Models, and Related Terms
MIL-STD-470	‘Maintainability Program Requirements (For Systems and Equipments)
MIL-STD-721	Definition of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety

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

3. DEFINITIONS

Meanings of terms not defined herein are in accordance with MIL-STD-280 and MIL-STD-721.

3.1 Maintenance Task. The maintenance effort necessary for retaining an item in, changing to, or restoring it to a specified condition, The procuring activity will provide to the contractor any terms that will be considered synonymous with the term task and will provide definitive criteria for determining different types of maintenance tasks and the timing of the tasks during verification/demonstration/evaluation.

3.2 Maintainability Model. A quantifiable representation of a test or process the purpose of which is to analyze results to determine specific relationships of a set of quantifiable maintainability parameters.

3.3 Verification. The contractor effort, monitored by the procuring activity, from date of award of the contract, progressing concurrently through hardware development from components to the configuration item (CI); to determine the accuracy of and update the analytical (predicted) data obtained from the maintainability engineering analysis; to identify maintainability design deficiencies; and to gain progressive assurance that the maintainability of the item can be achieved and demonstrated in subsequent phases.

3.4 Demonstration. The joint contractor and procuring activity effort to determine whether specifice maintainability contractual requirements have been achieved.

3.5 Evaluation. The procuring activity effort to determine, at all levels of maintenance, the impact of the operational, maintenance and support environment on the maintainability parameters of the item and to demonstrate depot level maintenance tasks.

3.6 Development Test and Evaluation (DT&E). Test and evaluation which focuses on the technological and engineering aspects of the system, subsystem, or equipment items.

3.7 Operational Test and Evaluation (OT&E). Test and evaluation which focuses on the development of optimum tactics, techniques, procedures, and concepts for systems and equipment, evaluation of reliability, maintain-ability and operational effectiveness, and suitability of systems and equip-ment under realistic operational conditions.

3.8 Maintenance Concept. A description of the planned general scheme for maintenance and support of an item in the operational environment.

3.9 Maintenance Environment. The climatic, geographical, physical and maintenance and support conditions (e.g., combat, mobil, continental) under which an item will be maintained.

4. REQUIRENENTS

4.1 General. Maintainability (M) verification, demonstration, and evaluation shall be performed in-accordance with the M test plan (see 4.2) prepared by the contractor and approved by the procuring activity. The M test plan shall for a part of the integrated support plan when an integrated support plan is required. The M test plan shall be prepared and submitted as part of the contractor's proposal, and progressively updated as design, development, and fabrication proceed. It shall be available for in process review by the procuring activity. Those portions of the total M test plan applicable to specific phases (verification, demonstration, evaluation) shall be submitted to the procuring activity for approval prior to its implementation and no later than the date specified by the contract. The M test plan shall be totally responsive to the qualitative and quantitative requirements and supplemental information contained in the procurement documents and the M program plan required by MIL-STD-470, "Maintainability Program Requirements." The supplemental information shall include, but not be limited to, maintenance concept, maintenance environment, skill levels of personnel, level(s) of maintenance to be demonstrated, and modes of operation for test, including configuration and missions. Coordination of the M verification, demonstration, and evaluation with other required demonstrations shall be accomplished whenever possible to avoid unnecessary duplication of effort. The environment and procedures shall represent, as closely as practical, that which can be expected in the intended operational use of the item. The plan, when applied to the system level, shall embody the three (3) phases: verification (Phase I); demonstration (Phase II); and evaluation (Phase 111)。 When the plan is applied to less than system level, the procuring activity shall specify the applicable phases, Figure 1 depicts a general tine-phase relationship of the three (3) phases. It should be recognized that Figure 1 depicts a general time-phasing only, which may differ for individual procurements. The procuring activity will provide guidance to the contractor as to the relationship between system life cycle phases and the verification/demonstration/evaluation phases. Of particular importance to the accomplishment of the procedures contained in this standard is the detailed information contained in the contractor's maintainability analysis as defined in MIL-STD-470. This analysis must contain a comprehensive description of the predicted maintenance tasks. For example, the maintainability analysis shall contain the following:

a. Failure mode or symptom and "how malfunction code," which would initiate the corrective maintenance task.

b. Frequency of occurrence of each failure mode and symptom of every maintenance task.

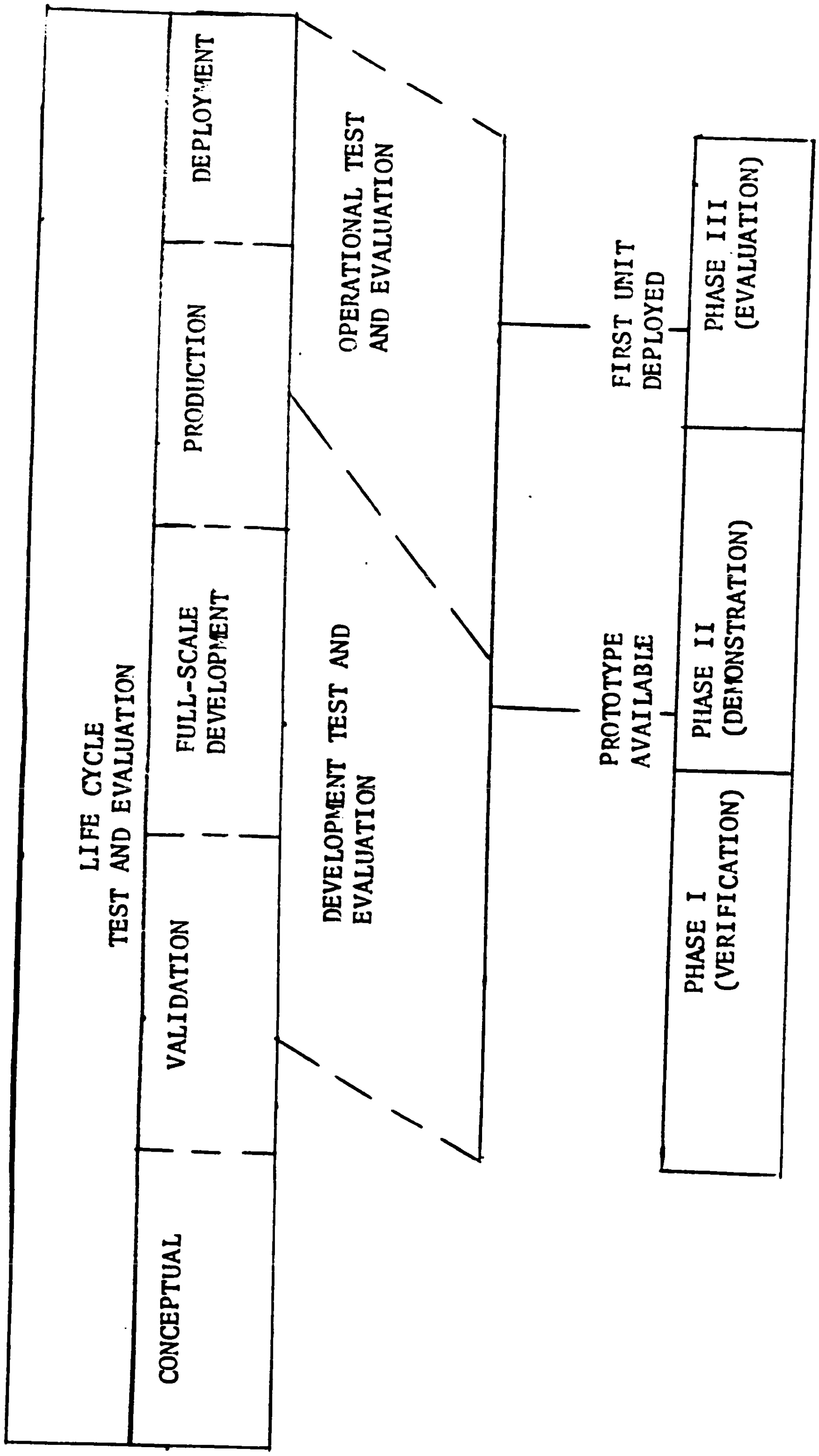


FIG. 1 - TIME PHASED CHART FOR MAINTAINABILITY
VERIFICATION/DEMONSTRATION/EVALUATION

c. Appropriate "action taken codes" and "work unit codes" for each maintenance task.

d. Predicted times for each element of maintenance time as defined in MIL-STD-721.

e. Skill levels and number of people required for each maintenance task.

f. Support equipment and tools required for each maintenance task.

g. Technical order interface for each maintenance task.

h. Identification of preventive maintenance tasks.

i. Identification of those maintenance tasks which are not normally or under any circumstances will not be prmitted to be performed concurrently with other maintenance tasks. It is assumed that all other maintenance tasks can be performed unrestricted by the performance of on-going maintenance.

4.1.1 Phase I. During Phase I, the contractor shall conduct an incremental verification effort, commencing with initial design and continuing through hardware development from components to the configuration item. The basic objectives of this phase are:

4.1.1.1 To verify and uqdate the contractor's maintainability model.

4.1.1.2 To insure economical correction of design deficiencies and to provide assurance that maintainability requirements will be achieved and demonstrated, by performing early in the design process, M verifications such as limited low confidence maintainability tests, time-motion measurements or such other tests as may be proposed by the contractor, subject to approval by the procuring activity.

4.1.1.3 To provide progressive assurance that the maintainability requirements can be achieved and demonstrated and that elements of the integrated support plan directly related to M are valid.

Maximum use shall be made of data resulting from maintenance performed in conjunction with such tests as development, prototype, mock-up, qualification, and reliability tests. When the procurement documents specify that the maintainability demonstration shall be part of Phase 1, the M demonstration and requirements of Phase II (see 4.1.2) shall apply.

4.1.2 Phase II. The objective of this phase is to determine during Development, Test and Evaluation (D, T&E) whether all specified M contractual requirements, except as noted under Phase III have been achieved. During this phase, the procuring activity will manage and conduct a maintainability demonstration as part of the total system demonstration. For those procurements which do not require a total system demonstration, the maintainability demonstration to be conducted during Phase II shall be an extension of Phase I. To assure acceptability of recorded data and resultant analysis, the contractor shall participate to the extent provided in 4.4 of this standard. The following requirements apply to all maintainability demonstrations. Additional requirements or changes may be imposed on individual procurements.

4.1.2.1 The maintainability demonstration shall be conducted in an environment which simulates, as closely as practicable, the operational and maintenance environment planned for the item. This environment shall be representative of the working conditions, tools, support equipment, spares, facilities, and technical publications that would be required during operational service use at the maintenance level defined in the approved maintenance plan.

4.1.2.2 Government personnel assigned to the test organization shall operate and maintain the demonstration items (see 4.2.3 and 4.4.1). When demonstration is conducted as an extension of Phase 1, the procuring activity shall specify the personnel (Government or contractor) who will operate and maintain the items.

4.1.2.3 In conjunction with the maintainability demonstration, the approved integrated support plan, when required, and established by the contractor, scaled to the number of test items employed in the demonstration, shall be implemented by the test team to identify the logistic support provided during Phase II.

4.1.2.4 All maintenance data, including depot level, shall be recorded and reported to the test team as specified by the procuring activity.

4.1.2.5 Unless approved otherwise by the procuring activity, the configuration of the items of the system selected for M demonstration shall be documented and certified by a physical configuration audit (PCA).

4.1.2,6 Unless approved otherwise by the procuring activity, all support equipment used during the demonstration shall be certified by PCA.

4.1.2.7 Maintenance tasks which may require fault simulation (see 4.3.1.2 and 4.3.1.3) shall require that the item be checked for normal operation prior to failure simulation and after completion of the specified maintenance task. When a failure is simulated, it will be the responsibility of the test team to select the maintenance task, the failure to be simulated, and the failure mode; and to verify that the degree of failure is representative of the maintenance task to be demonstrated. The work area in which parts degradation or failure has been simulated shall contain no obvious evidence other than that normally resulting from the simulated mode of failure. The appearance of defective parts that are substituted for serviceable parts shall be that of a normally failed part. The technician shall not witness any fault insertion. Simulation of failures by introduction of faulty parts will not be used when the normal procedures could result in extensive damage to the equipment or item being tested. Each defective part is to be installed in the equipment in the same manner as the original part.

4.1.2.8 For maintenance tasks, whose faults have been simulated, the presence of necessary spares, tools, test and support equipment, or technical publications shall not assist in fault isolation by prematurely identifying the work to be done. Such items shall be covered or otherwise kept out of sight from the technician. However, simulated discrepancy data shall be made available, if applicable.

4.1.2.9 Maintenance personnel performing maintenance tasks for the demonstration shall be military or civil service personnel, with the exception that contractor personnel will perform those tasks specified to be performed by contractual personnel during the operational service use (see 4.1.2.2) . Technicians shall have received the training and be of the equivalent skill level as specified in the standard personnel resource documentation for the specified level of maintenance. Exception to the training and skill level requirements may be made for specified tasks which will be performed by contractor personnel during operational service use.

4.1.2.10 Each maintenance task will be documented by personnel designated by the test team. The total time measured for a technician to perform each maintenance task shall be recorded and will include the time to perform each element of maintenance time defined in MIL-STD-721. Each element will be documented separately. The total delay time for each maintenance task shall be documented. The test plan and procedures shall include delay time rules.

4.1.2.11 The time required to obtain support items (appropriate test and support equipment, tools, spare parts, technical publications, etc.) from the defined work center area shall be recorded. This time shall not, however, be chargeable as maintenance task time for the item being demonstrated unless this time is controlled or influenced by the design of the item being demonstrated, 4.1.2.12 Items to be furnished by the contractor shall be provided in the type, quality, and quantity required for planned operation requirements scaled to the demonstration and evaluation requirements, prior to the start of the phase being perfomed. Items to be furnished by the procuring activity shall be identified and requested by the contractor in time to be available prior to the start of the phase being performed.

4.1.3 Phase III. The objective of this phase is to (1) evaluate the impact of the actual operational, maintenance, and support environment on the maintainability parameters of the system, (2) to evaluate the correction of deficiencies exhibited during Phase II, and (3) to demonstrate depot level maintenance tasks when applicable. A maintainability evaluation will be managed and conducted, by the procuring activity, during Operational, Test and Evaluation as part of the total system evaluation, To assure acceptability of recorded data and resultant analysis, the contractor shall participate in Phase III to the extent described in 4.4 of this standard or as otherwise provided. The same conditions outlined for Phase II (see 4.1.2) shall apply, except for the following:

4.1.3.1 All evaluation items shall be production or production equivalent models.

4.1.3.2 The evaluation shall be conducted in the actual operational and maintenance environment unless otherwise directed by the procuring activity.

4.1.3.3 All maintenance tasks will be accomplished by military or civil service personnel with the exception that contractor personnel will perform those tasks specified to be performed by contractual personnel during operational service use.

4.1.3.4 Depot level maintenance tasks shall be demonstrated and the data collected applied to the maintainability demonstration and evaluation.

4.1.3.5 Maintenance tasks to be evaluated shall be those resulting directly from and incidental to actual operation and maintenance. These tasks shall be supplemented by fault simulation only to evaluate specific tasks or special tasks (see 4.3.1.3) that do not occur by chance during the evaluation phase.

4.2 Maintainability Verification/Demonstration/Evaluation Plan. The plan, prepared by the contractor in accordance with the Contract Data Requirements List (CDRL), shall include the following sections, as a minimum, identified with each of the three (3) phases, unless instructions to the contrary are provided in the specific procurement. Certain sections cover material subject to other, more specific, contractual requirements and nay be included in the plan as they are prepared in response thereto. They are included to insure adequate attention and continuity.

4.2.1 Background Information. A description of:

4.2.1.1 Quantitative and qualitative maintainability requirements;

4.2.1.2 Maintenance concept;

4.2.1.3 Maintenance environment;

4.2.1.4 Level(s) of maintenance;

4.2.1.5 Sites;

4.2.1.6 Facilities' requirements;

4.2.1.7 Participating agencies;

4.2.1.8 Mode(s) of operation of the items, including configuration and mission requirements;

4.2.1.9 Items subject to verification, demonstration and evaluation; and

4.2.1.10 Contractual data required for completion of the verification/demonstration/evaluation.

4.2.2 Item Interfaces. A description of the adequacy or inadequacies of the item support elements and an estimate of their effect on the item maintainability. These elements would include the following:

4.2.2.1 Maintenance planning;

4.2.2.2 Support and test equipment;

4.2.2.3 Supply support;

4.2.2.4 Transportation, handling and storage;

4.2.2.5 Technical data;

4.2.2.6 Facilities; and

4.2.2.7 Personnel and training.

4.2.3 <u>Test Team.</u> A description of:

4.2.3.1 Organization;

4.2.3.2 Degree of contractor and procuring activity participation, including managerial, technical, maintenance, and operation personnel;

4.2.3.3 Assignment of specific responsibilities; and

4.2.3.4 Qualifications, quantity, sources, training, and indoctrination requirements for the test team personnel.

4,2.4 <u>Support Material.</u> A description of:

4.2.4.1 Support equipment;

4.2.4.2 Tools and test equipment;

4.2.4.3 Technical manuals;

4.2.4.4 Spares and consumables;

4.2.4.5 Safety equipment; and

4.2.4.6 Calibration equipment.

4.2.5 <u>Preparation Stage.</u> A description of and schedule for:

4.2.5.1 Organization and assembly of the test team;

4.2.5.2 Training of personnel;

4.2.5.3 Preparation of facilities; and

4.2.5.4 Availability, assembly, checkout, and preliminary validation of support material.

4.2.6 <u>Verification/Demonstration/Evaluation Stage.</u> A description of:

4.2.6.1 Test objectives;

4.2.6.2 Schedule of tests;

4.2.6.3 Procedure for selection of maintenance tasks when faults are simulated (see 4.3.1.2);

4.2.6.4 Identification of special maintenance tasks (see 4.3.1.3);

4.2.6.5 Test method, including accept/reject decision criteria, risks, etc.;

4.2.6.6 Data acquisition method;

4.2.6.7 Data analysis methods and procedures;

4.2.6.8 Specific data elements;

4.2.6.9 Units of measurement;

4.2.6.10 Type and schedule of reports;

4.2.6.11 Schedule of maintenance task accomplishment such as time change compliance tasks, inspection, lubrication, and turn around tasks; and

4.2.6.12 The maintenance tasks, other than those listed in 4.2.6.11, to be verified, demonstrated, and evaluated. These tasks may be prepared and submitted in a referenced document.

4.2.7 Retest Stage. A provisional schedule for special or repeat tests to investigate deficiencies or trouble arreas. Deficiencies shall be corrected in any item which has failed to meet the acceptance criteria. The corrected portions of the item and any other portions of the item affected by the correction shall be retested during this stage. The maintenance tasks to be demonstrated shall be as designated by the procuring activity.

4.3 Test procedures. In designing the maintainability test procedures, both qualitative and quantitative requirements shall be verified, demonstrated, and evaluated. Unless instructions to the contrary are provided in the specific procurement contractual documentation, qualitative maintainability requirements will be verified, demonstrated, and evaluated using contractor prepared checklists. These checklists, to be approved by the procuring activity, will permit observation, analysis, and identification of maintainability characteristics incorporated or omitted. Quantitative requirements shall be verified, demonstrated, and evaluated by actual demonstration of maintenance tasks.

4.3.1 Maintenance Tsk Generation. All maintenance tasks shall be performed at the maintenance level approved by the procuring activity and in accordance with the approved maintenance plan. Maintenance tasks, both corrective and preventive, shall be generated by the following methods as identified in the final approved maintainability verification, demonstration, and evaluation plan.

4.3.1.1 Actual operation of the item in the specified test, operational, and maintenance environment. This method is preferred, provided that assurance can be given that sufficient number of maintenance tasks will occur during the test period to satisfy the minimum sample requirements for the test method employed (see Appendix B).

4.3.1.2 Fault simulation by introduction of faulty parts, deliberate misalignment, open leads, shorted parts, etc. A maintenance task sampling plan shall be prepared by the contractor in accordance with the procedure described in Appendix A or as directed by the procuring activity for approval by the latter. The actual task selection, by the test team, shall not be accomplished until immediately prior to the demonstration.

4.3.1.3 "Special" maintenance tasks which require unique skills, equipment, test methods, etc., will be selected by the procuring activity. The method of demonstrating these tasks will be specified by the procuring activity.

4.3.2 Turnaround Tasks. Tasks comprising turnaround shall be demonstrated. These tasks shall be determined from the planned operational use of the item.

4.3.3 Test Method. Statistical test methods and criteria for deciding whether specified maintainability requirements have been met are described in Appendix B. Guidance on selection and application of the test methods is included with each, Selection of the test method shall be from Appendix B, subject to procuring activity approval or as otherwise specified.

4.4 Administration. The following shall apply in the administration of the verification, demonstration and evaluation of the maintainability of the item.

4.4.1 Test Team Responsibility. The procuring activity/contractor verification, demonstration, and evaluation team(s) for each of the three (3) applicable phases-shall be empowered to make decisions for their respective organizations. Each member of the team may have advisors from his organization who are knowledgeable in the various aspects of the dmonstration and the requirements of the verification/ demonstration/evalution plan. The responsibilities of the team are in accordance with the contractors approved maintainability verification/ demonstration/evaluation plan and shall include, but are not limited to the following:

4.4.1.1 To maintain surveillance over maintenance and inspection operations. Any apparent discrepancies in maintenance task accomplishment and documentation observed by any member of the team will be brought to the attention of the remaining test team members within one working day of the occurrence for appropriate action.

4.4.1.2 To evaluate and validate maintenance and operational data to determine applicable manhours, flying hours, operating time, maintenance time, downtime, item status, etc.

4.4.1.3 To assure that the demonstration item selected has been adequately prepared in accordance with applicable technical manuals and that no maintenance has been deferred that will compromise the successful completion of the next scheduled operation or mission prior to being placed in an operational ready status.

4.4.1.4 To decide if rsulting failures, maintenance time, elapsed downtime, maintenance manhours, etc., should be chargeable in cases where operator or maintenance crew errors have been committed.

4.4.1.5 To rule on questions of whether or not the verification, demonstration, and evaluation plan has been adhered to.

4.4.1.6 To rule on controversial points which may arise that are not specifically covered by applicable specifications or other pertinent documentation. To determine those matters which require contractual interpretation or resolution by the appropriate government and contractor organizations. For these matters, the test team majority and minority statements shall be submitted to the procuring activity contracting officer for resolution.

4.4.1.7 To prepare and submit demonstration status reports to the procuring activity and the contractor.

4.4.1.8 To analyze data and determine the extent of achievement of specified maintainability requirements.

4.4.1.9 To prepare and submit final results of each of the phases to the procuring activity and the contractor within the time period indicated in the approved test plan.

4.4.1.10 To assure that the following conditions have been fulfilled prior to the start of Phase II and Phase III and that a letter has been sent to the procuring activity which so attests.

4.4.1.10.1 Each test item complies with the established configuration or that all deviations reported have been accepted by the procuring activity. It shall be the responsibility of the contractor to report all deviations from the approved configuration.

4.4.1.10.2 All required technical manuals have been updated as necessary.

4.4.1.10.3 The support resources are available in the type and quantity specified in the verification, demonstration, and evaluation plan.

4.4.1.10.4 All operator or maintenance crew personnel are properly trained and meet established skill level requirements.

4.4.1.10.5 All records of approved changes in personnel requirements, operating and maintenance manuals, data handling procedures, and analysis techniques have been incorporated in the final revision of the verification, demonstration, and evaluation plan.

4.4.2 Test Director. An individual, designated by the procuring activity, as test director, shall decide in all cases of deadlock between the members of the team (subject to contract negotiations where contractual obligations are in question).

4.4.3 Instrumentation Failures. Any failures of test instrumentation used to instrument the demonstration item for test purposes or failures induced by such test instrumentation installation or operation, and all associated maintenance, shall not be chargeable.

4.4.4 Maintenance Due To Secondary Failures. If any secondary failres result from a chargeable primary failure, the total resultant maintenance time to restore the items shall be chargeable as a single maintenance task, except when the secondary failure results from the method used to simulate a fault rather than from the fault itself. If the reason for the secondary failure is removed (corrected), the time charge for the secondary failure shall be deleted.

4.4.5 Inadequate Technical Manuals Or Support Equipment. If, in the accomplishment of a maintenance task, a technician finds the applicable technical manuals or support equipment to be inadequate, these-instances shall be brought to the attention of the test team and, if the inadequacy is verified, this portion of the demonstration shall be terminated and times measured shall not be chargeable, Action shall be taken to correct the inadequacies of the technical manuals or support equipment, after which the same maintenance task shall be repeated.

4.4.6 Cautions. If an item is damaged or maintenance errors induced by item design complexity, by poor design practice, or by following improper procedures that allow improper maintenance (e.g., interchangeability of connectors] without proper caution in the technical manuals. the failure and resultant maintenance times shall be chargeable. Action shall be taken to correct the improper procedures or deficiencies and the corrective action verified. When this action is completed, the maintenance time saved shall be deleted.

4.4.7 Personnel Number and Skill. Each task shall be performed by the prescribed number of personnel with the prescribed specialty codes and skills. If personnel are required on an intermittent or sequenced basis, the manhours assessed against the maintenance task will include the required standby time only-if the standby time is of a type or duration which prevents standby personnel from performing other productive tasks.

4.4.8 Cannibalization. The maintenance associated with the removal or reinstallation of the item or support equipment assemblies and/or components for cannibalization purposes shall not be chargeable unless the-deficiency can be directly related to lack of contractor recommendations for proper level of support spares or expendables. If the contractor takes action to correct the deficiency, the time charged shall be deleted.

4.4.9 Availability. An item shall be considered in an operationally available or operationally ready status (for aircraft) if-it is capable of performing in accordance with the item's specification or capable of performing the next scheduled assigned mission.

4.4.10 Maintenance Inspection. The look portion of any inspection such as pre-flight, post-flight, or phase of a phased inspection shall be considered a separate preventive maintenance task. Each fix of the fix portion of an inspection shall be considered a separate corrective maintenance task.

4.5 GFE/GFAE Items. For Government Furnished Equipment (GFE) and Government Furnished Aeronautical Equipment (GFAE) items, the contractor is responsible for determining the CFE/GFAE maintainability characteristics and values required for his Configuration Item (CI), and for assuring that the GFE/GFAE maintainability characteristics and values are not degraded unless compensated for by the demonstrated characteristics and values for other Contractor Furnished Equipment (CFE) or GFE/GFAE The government will furnish data on known or estimated values of GFE/GFAE reliability and maintainability which shall be used, as applicable, in the contractor's judgment. The contractor is responsible for estimating and demonstrating the maintainability requirements of the entire CI.

4.6 Data Collection. The data collection system used in Phase I and data elements collected shall meet the needs of the objectives of Phase 1. In addition, the data system and data elements shall be compatible with the data system used and data elements collected in Phases II and III. During Phase II and Phase III, the test team shall establish and operate a data center. All data recorded by the test team shall be made available to the contractor through the data center. The test team shall utilize the data system specified by the procuring activity, to record all mission debriefing, failure and maintenance data. The contractor shall describe maintenance tasks in a manner which will allow proper identification within the services maintenance data collection system that a particular task has occurred. For example, when using the System Effectiveness Data System (SEDS), the maintenance task description must contain a Work Unit Code, How Malfunctioned, and Action Taken Code which uniquely identify that task. Supplementary data collection may be incorporated if approved by the procuring activity. For those items which the contractor has depot level repair responsibilities, he shall be responsible for preparation, accuracy, and feedback of the depot level verification, demonstration, evaluation maintenance data for all depot repairable generated. All depot level data elements collected shall be compatible with the data elements collected and recorded at the organizational and intermediate maintenance levels. All direct maintenance downtime or manhours, as applicable, which is not specifically determined to be nonchargeable shall be included in the demonstration data and in the calculated quantitative value which determines compliance or noncompliance. Maintenance which might not be chargeable could result from such causes as:

4.6.1 Maintenance and operational errors not chargeable to technical manuals, contractor furnished training or faulty design.

4.6.2 Miscellaneous tasks such as keeping of records, taxiing and towing of aircraft to or from an area other than the assigned work center area.

4.6.3 Repair of accident damage.

4.6.4 Documented delay downtime (supply or administrative) which is clearly outside the responsibility of the contractor.

4.6.5 Modification tasks.

4.6.6 Maintenance of test instrumentation exclusive of normal configuration.

4.6.7 Maintenance time accountable to test instrumentation installations (other than normal configuration) accrued during maintenance task perfomnance.

4.7 Maintainability Parameter Calculations. All data acceptable to the team and generated by the demonstration shall be used in calculating the M parameters. The following are typical maintainability parameters which may be stated in the specification: Mean-Time-To-Repair (MTTR), manhour rate, critical maintenance time or manhours, critical percentile, and chargeable maintenance downtime (a parameter for demostration of availability). Appendix B provides methods for calculating these values and the criteria for determining whether the requirements have been achieved. Other methods of calculation tailored to 2 specific procurement may be provided/approved by the procuring activity.

4.8 Maintainability Verification/Demonstration/Evaluation Reports. A final report shall be submitted by the test team, after each phase, to the procuring activity in accordance with the schedule incorporated in the verification/demonstration/evaluation plan and the data requirements per Contractor Data Requirements List (DD Form 1423). The procuring activity may require interim reports where additional detail or extended test durations may be involved. The final report shall include, as a minimum, the following:

4.8.1 Summary of data collected and location of data file.

4.8.2 Factors which influence the data.

4.8.3 Analysis of the data.

4.8.4 Results of the phase and certification that the specified objectives and requirements have or have not been met.

4.8.5 Assessment of the integrated logistic support factors, such as technical manuals, personnel, tools and test equipments, support equipment, maintenance concept and provisioning for their effect on quantitative and qualitative demonstrated maintainability parameters.

4.8.6 Deficiencies.

4.8.7 Recommendations:

4.8.7.1 to correct deficiencies and

4.8.7.2 for suggested improvements.

4.8.8 Results of retest (if applicable). To be submitted as a supplement to the final report.

5. ORDERING DATA

The selected data requirements in support of this standard shall be reflected in the Contractor Data Requirements List (DD Form 1423) attached to the Request for Proposal, Invitation for Bid, or the Contract, as appropriate. The following information will be included in the applicable contractual documents:

a. Phases applicable to the procurement (see 1.2).

b. Dates for submission of the test plan and test procedures for each phase (see 4.1, 4.2).

c. Type of personnel (government or contractor who will operate and maintain the item for maintainability demonstration) (see 4.1.2.2).

d. Dates for submission of the final, interim and supplemental (if required) reports for each phase (see 4.8).

e. Data collection system (4.6).

f. Specification Requirements and Test Method (see Appendix B; B.10.2 for major characteristics for the test method specified).

CUSTODIANS

Army - EL
Navy - AS
Air Force - 17

REVIEW ACTIVITIES

Amy - EL, MI, SC, TE
Navy - EC
Air Force - 10, 11, 13, 15, 22, 26

USER ACTIVITIES

Army -
Navy -
Air,Force - 19, 71, 80

PREPARING ACTIVITY

Air Force - 17
Project MISC-0855

APPENDIX A

MAINTENAINCE TASK SAMPLING FOR USE WITH FAILURE SIMULATION

A.100 SCOPE.

A.10.1 Purpose. This appendix outlines a procedure for the selection of a sample of corrective maintenance tasks for maintainability demonstration when the tasks result from failure simulation.

A.10.2 Application. The procedure described herein is applicable only when failure simulation is to be used to generate maintenance tasks. The procedure is applicable to the equipment level and it is assumed that system level maintainability requirements have been allocated to the equipment level for demonstration. The mean estimates for equipment may be employed to determine achievement of system maintainability requirements. If sampling of preventive maintenance tasks or servicing is permitted, a procedure and tables similar to that illustrated in this appendix for corrective maintenance must be developed for each type of task (i.e., preventive maintenance, servicing].

A.10.3 Sample Stratification. A major objective of stratification is to divide a heterogeneous population into homogeneous. subpopulations or strata. Selection of a sample of maintenance tasks from a stratum will yield a representative sample of that stratum. The sum of samples from all strata should represent the total maintenance task population. Proportional stratified sampling may be used for selection of maintenance tasks to be demonstrated using the fixed sample size test methods described in Appendix B. Sequential test method shall employ simple random sampling.

A.10.4 Stratification Procedure. The following example illustrates the procedure for tasks which would be classified as corrective maintenance. Preventive maintenance or servicing tasks would not be combined with corrective maintenance tasks for the purpose of task stratification. For system level demonstration of maintainability requirements, the procedure would be applied to each equipment and through appropriate techniques, the achievement of system maintainability requirements may be demonstrated. Maintenance tasks may be performed concurrently or serially provided that provision has been made to record the expended maintenance time for each maintenance task. The requirement to be demonstrated shall determine the manner in which the data shall be analyzed. The following, Table I, illustrates the application of this procedure to a radar equipment consisting of: Antenna, Receiver/Transmitter, Frequency Tracker, Radar Set Control, and Drift Angle Indicator:

a. Column 1 - Identify the major units which comprise the equipment.

b. Column 2 - Subdivide each unit to the functional level at which maintenance for the demonstration is to be performed in accordance with the approved maintenance plan. This level may be an assembly, module, printed circuit card or piece part.

c. Columns 3 & 4 - For each functional level of maintenance identified in Column 2, identify in Column 3 the maintenance task or tasks to be performed and in Column 4 the estimated mean maintenance time for the task. The maintenance task time shall include the time to perform each element of maintenance time as defined in MIL-STD-721B. The maintenance tasks and estimated maintenance time would be derived from a maintenance engineering analysis, a maintainability prediction effort, or from historical data. The same maintenance task, such as "remove and replace" of a module may result from different faults within the module. Column 3 would identify the maintenance task and not the fault or failure which results in the occurrence of the task,

d. column s - Determine the failure rate (F/10^6 hr) for each module, printed circuit card, etc., for which the maintenance task was identified in Column 3 at the functional level of maintenance identified in column 2. The failure rates used shall be the latest available from the associated reliability program. If there is no reliability program, the failure rates may be selected or extrapolated from sources approved by the procuring activity.

e. Column 6 - Determine the quantity of items in each major unit associated with each task in Column 3.

f. column 7 - Determine the duty cycle for each item associated with each task in Column 3 (e.g., operating time of a receiver to the operating time of the radar; engine operating hours to aircraft flight hours).

g. Column 8 - Group together the maintenance tasks identified in Column 3 which have both:

(1) Similar maintenance actions. NOTE: A maintenance action is an element of a maintenance task. Although the estimated maintenance time for different maintenance tasks may be similar, the actions may be different, that is, one task may involve significant diagnostics and another involve minimum diagnostics but significant access time.

(2) Similar estimated maintenance times. The range of maintenance times for each group shall not vary more than ± 25 percent from the mean value of the group.

Task grouping shall be limited to within major units identified in Column 1.

h. Column 9 - Determine the total failure rate for each task grouping identified in Column 8. The total failure rate is equal to the sum of the products of Columns 5 x 6 x 7 for all tasks within the group.

i. Column - Determine the relative frequency of occurrence for each task grouping by dividing the sum of the total failure rate (sum of Column 9) into the individual total failure rate for each group.

j. Column 11 - A sample of maintenance tasks equal to at least four times the sample size specified for the selected test method (Appendix B) or as specified by the procuring activity, shall be allocated among the task groups in accordance with the relative frequency of occurrence of the task group. Example: Assume the test method to be employed requires that a sample of 50 maintenance tasks be demonstrated, a sample of 200 tasks (4 x 50) shall be allocated among the task groups as follows:

Group 1 - 17.7 percent x 200 - 35 tasks;

Group 2 = 17.8 percent x 200 = 36 tasks;

Group 3 = 1.6 percent x 200 = 3 tasks, etc.

This allocation is shown in Column 11. The maintenance tasks allocated to each group shall be randomly selected and identified from the population of maintenance tasks applicable to that group. The total number of maintenance tasks which must be identified for the equipment must be equal to or greater than four times the demonstration sample size (i.e., greater than 4 x 50 = 200 for this example) in order that the number of tasks identified with each l group is sufficient such that the allocation of tasks to each group (i.e., 35 tasks for Group 1; 36 tasks for Group 2, etc.), may be randomly selected from the population of tasks identified as applicable to that group. The maintenance tasks which have been randomly selected shall not be returned to the sample pool. When a task group consists of more than one module or assembly, etc., such as group 2 of Table I, the maintenance tasks assigned to the group (Column 11, 36 tasks for this example) shall be allocated to the modules, assemblies, etc., within the group in accordance with the relative frequency of occurrence of maintenance for each module, etc., within the group. The procedure would be the same as that used to determine the relative frequency of occurrence of the task groups (Column 10) but would be applied to the modules, etc. , within the group. This is illustrated below with the allocation shown included in Table I, Column 11, Group 2.

Group 2	Total Failure Rate	Relative Freq. of Occ.	Demonstration Population Allocation
A-IF-A	23	.217	7.8 ≈8 (.217 X .6 = 7.8)
B-IF-B	21	.198	7.4 ≈7
C-Amplifier	21	.198	7.1 ≈7
D-Modulator	18	.170	6.0 6
E-Power Supply	23	.217	7.8 ≈8
	106	1.000	36

k. Column 12 - The maintenance tasks to be demonstrated (50 tasks for this example) shall be allocated among the task groups in accordance with the relative frequency of occurrence of maintenance for the group.

Example:

Group 1: 17.7 percent x 50 = 8.85 ≈ 9 tasks

Group 2: 17.8 percent x 50 = 8.90 ≈ 9 tasks

Group 3: 1.6 percent x 50 = ,80 ≈ 1 task, etc.

If a task group consists of more than one module, assembly, etc., group 2, Table I, the maintenance tasks to be demonstrated from the group (column 12, 9 tasks for this example) shall be allocated to the modules, assemblies, etc., within the group in accordance with the relative frequency of occurrence of maintenance for each module, etc., within the group. is illustrated below with the sample allocation shown included in Table 1, column 12.

Group 2	Relative Freq. of Occurrence	Demonstration Same Size
IF-A	.217	1.95 ≈ 2 .217 X 9 = 1.95
IF-B	.198	1.78 ≈ 2
Amplifier	.198	1.18 ≈ 2
Modular	.170	1.53 ≈ 1
Power Supply	.217	1.95 ≈ 2
		9 total

The maintenance task to be demonstrated shall be randomly selected from the maintenance tasks allocated to the group or modules, assemblies, etc., within the group or modules, assemblies, etc., within the group (column 11). The maintenance task to be demonstrated shall not be returned to the sample pool and shall be demonstrated once only unless otherwise permitted by the procuring activity.

1. Column 13 - Variable Sample/Sequential Test - When variable sample size, sequential test methods are employed a simple random sampling of the total population of maintenance tasks using a random number table based on a uniform distribution from 0 to 1 shall be used. Using Table I columns 1 through 10 determine from the relative frequency of occurrence (column 10), the cumulative range of frequency of occurrence for each task group. A maintenance task is selected from that group whose cumulative range of frequency of occurrence includes the number selected from the random number table. The number selected from the random number table shall be "returned" to the table before selecting a second number. The "specimen" task demonstrated shall be returned to the sample pool.

A.10.5 Failure Mode Selection. A failure mode and effect analysis (FMEA), applied to the functional level at which maintenance is to be performed, shall be used to determine the failure modes or faults (open, short, etc.), which will result in the occurrence of the maintenance task of interest. To avoid duplication of effort, the FMEA shall utilize inputs from and be coordinated with the reliability program efforts. The relative frequency of occurrence of the failure mode will determine the fault to be simulated, This procedure is illustrated in Table II.

a. Column 1 - Identify the maintenance task of interest.

b. Column 2 - Determine the failure modes which will result in the maintenance task of interest.

c. Column 3 - Determine the effect of each failure mode identified in column 2.

d. Column 4 - Determine the relative frequency of occurrence of each failure mode.

e. Column 5 - Simple Random Sampling - Determine the cumulative range of frequency of occurrence for each failure mode. Using a random number table a number is selected and the failure mode to be induced is that whose cumulative range of frequency of occurrence includes the number selected. The number selected from the random number table shall be "returned" to the table before selecting a second number. The specimen demonstrated shall be returned to the sample pool.

TABLE I - STRATIFICATION PROCEDURE

Equipment - Radar XYZ

(1) Major Units	(2) Functional Level of Maintenance	(3) Maintenance Task	(4) Est. Mean Maint. Time (hrs)	(5) Failure Rate F/10^6 hrs.	(6) Quantity of Items	(7) Duty Cycle	(8) Task Grouping	(9) Total Failure Rate	(10) Relative Freq. of Occurrence	FIXED SAMPLE (11) Demon. Population Allocation	FIXED SAMPLE (12) Demon. Sample Size	VARIABLE SAMPLE (13) Cumulative Range
Antenna	Antenna	R/R(A)	1.0	105	1	1.0	Group 1 Task A	105	0.177	35	9	0 - .1769
Receiver/ Transmitter	IF-A	R/R(A)	0.3	23	1	1.0	Group 2 Tasks A, B,C,D,E	106	0.178	A-8	A-2	
	IF-B Amplifier	R/R(B)	0.3	21	1	1.0				B-7 36	B-2 9	.1770 - .3549
	Modulator	R/R(C)	0.4	21	1	1.0				C-7	C-2	
	Power Supply	R/R(D)	0.4	18	1	1.0				D-6	D-1	
	Transmitter	R/R(E)	0.4	23	1	1.0				E-8	E-2	
		R/R(F)	0.5	10	1	1.0	Group 3 Task F	10	0.016	3	1	.3550 - .3709
Freq. Tracker	Freq. Tracker	R/R(A)	0.6	400	1	.7	Group 4 Task A	280	0.472	94	23	.3710 - .8429
		Replace Crystals(B)	0.5	20	4	.7	Group 5 Task B	56	0.094	19	5	.8430 - .9369
Radar Set Control	Radar Set Control	R/R(A)	0.5	35	1	.8	Group 6 Task A	28	0.047	10	2	.9370 - .9839
Drift Angle Indicator	Drift Angle Indicator	R/R(A)	0.5	10	1	.8	Group 7 Task A	8	0.013	3	1	.9840 - 1.00
								593	1.00	200	50	

NOTE 1: R/R = remove/replace (includes time to perform each element of maintenance time as defined in MIL-STD-721).

NOTE 2: This table is for illustration only. It is not intended to represent a complete radar nor should the entries be considered as real data.

NOTE 3: Delete column 11 and column 12 for sequential test methods.

TABLE II

FAILURE MODE SELECTION

1 Maintenance Task	2 Failure Mode	3 Effect	4 Relative Frequency of Occurrence (Percent)	5 Cumulative Range (Percent)
Receiver Remove/ Replace	1. Component out of tolerance	1. Noise	.20	0 - .199
	2. Component shorted/open	2. Receiver Inoperative	.35	.200 - .549
	3. Tuning failure	3. Cannot change frequency	.45	.550 - 1.00

NOTE: This table is for illustration only and does not reflect real failure modes, etc.

APPENDIX B

TEST METHODS AND DATA ANALYSIS

B.10 Scope.

B.10.1 Purpose - This appendix contain test methods and criteria for demonstrating the achievement of specified quantitative maintainability requirements.

B.10.2 Application - The following matrix (Fig. B-1) summarizes the major characteristics of each test method as well as the quantitative requirements which must be specified for each test method. The data analysis method included with each test method provides the decision criteria for acceptance or rejection of the item being demonstrated.

B.10.3 Sample Size - Each of the test plans contained in this appendix includes an equation or other directions for determining a minimum sample size of maintenance tasks. Any departure from the minimum sample size requirement can affect the statistical validity of the test procedures. Some of the test plans in the appendix require a prior estimate of the variance of the distribution of interest for the calculation of sample size. Such prior estimates, subject to government approval, can be obtained from data on similar equipment provided similarities in maintainability design, skill levels of maintenance personnel, test equipment, manuals and the maintenance environment are considered in the estimation process. Equations for predicting the variance when prior estimates are not available are presented in DDC document AD-869396, Maintainability Prediction and Demonstration Techniques, Vol. II, cited in para B.10.6, which can be used, provided the information needed for the prediction is available. The 85th - 95 th upper confidence bound on the predicted or estimated variance shall be used to insure preservation of desired risk values. Average observed values of the variance have ranged from $6^2 = .5$ to $6^2 = 1.3$.

B.10.4 Task Selection - Selection of tasks to be sampled when employing fault simulation will be made in accordance with Appendix A of this standard. Care must be exercised in selecting and sampling tasks to insure that a true simple random sample is obtained when sequential tests are employed. Departures from simple random sampling, such as proportionate stratified sampling, can effect the validity of the test procedures presented herein, however this effect is considered minimum for the sample sizes required by the test procedures. Simple random sampling shall be used for sequential tests.

B.10.5 Test Selection - In general, the test index to be demonstrated is the primary consideration in selecting a test procedure. Considerable savings in sample size can be obtained by use of sequential test procedures in preference to fixed sample tests. As a general rule, however, the sequential test should be wed only when prior knowledge (e.g., from the prediction) indicates that the equipment may be much better (or worse) than the specified values.

Test Method	Test Index	Assumed Distribution	Sample Size	Sample Selection	Spec. Requirement
1-A	Mean	Log Normal	See Test Method	Natural Occurring Failures or Appendix A	H_o, H_1, α, β (1)
1-B	"	None	"	"	"
2	Critical Percentile	Log Normal	"	"	"
3	Critical Maint. Time or Manhours	None	"	"	"
4	Median	Log Normal	"	"	ERT
5	Chargeable (2) Maint. Down-time/Flight	None	"	Natural Occurring Failures	ORR or A $\frac{NCMDT}{NOF}$, $\frac{DDT}{NOF}$, α, β
6	Manhour (3) Rate	None	"	"	Manhour Rate ΔMR
7	Manhour (4) Rate	None	"	Natural Occurring Failures or Appendix A	μ_R, α

(1) See B.10.7 for definitions of α, β, H_o, H_1

(2) Test Method 5 is an indirect method for demonstrating operational ready rate (ORR) or Availability (A).

(3) Test Method 6 is intended for use with aeronautical systems and subsystems.

(4) Test Method 7 is intended for use with ground electronic systems where it may be necessary to simulate faults.

Fig. B-1 - TEST METHOD MATRIX

The justification for use of the log-normal assumption for corrective maintenance times is based on extensive analysis of field data which have shown that the log-normal distribution provides a good fit to the data. However, in those cases where it is suspected that the log-normal assumption does not hold (e.g., equipments with a high degree of built-in diagnostics) then a distribution-free method should be employed to insure preservation of specified risks.

B.10.6 References - Details and additional references for the test plans (1, 2, 3) presented in this appendix can be found in RADC Technical Report 69-356 (AD 869 396), Volume II, entitled: 'Maintainability Prediction and Demonstration Techniques." Copies of this document may be obtained from the Defense Documentation Center, Camera Station, Alexandria, VA 22314.

B.10.7 Symbols - The following symbols and notations are common the test methods 1 - 3 contained in this appendix:

X = the random variable which denotes the maintenance characteristics of interest (e.g., X can denote corrective maintenance time, preventive maintenance time, fault location time, manhours per maintenance task, etc.).

X_i = the ith observation or value of the random variable X.

n = the sample size

$\bar{X}$ = the sample mean (i.e., $\bar{X} = \frac{1}{n}\sum_{i=1}^{n}(X_i)$)

$\sigma^2 = E\left[(\ln X-\theta)^2\right]$ = the true variance of lnX

$\mu = E(X)$ = the true mean of X.

$d^2 = Var(X) = E\left[(X-\mu)^2\right]$ = the true variance of X.

$\hat{d}^2$ = the sample variance of X (i.e., $\hat{d}^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i-\bar{X}^2)) = \frac{1}{n-1}\left(\sum_{i=1}^{n} X_i^2 - n\bar{X}^2\right)$

$\tilde{d}^2$ = the prior estimate of the variance of the maintenance time

X_p = the (1-p)th percentile of X (i.e., $X_{.05}$ = 95th percentile of X).

$\tilde{M} = X_{.50}$ = the median of X.

$Y = \ln X$ = the natural logarithm of X.

$\bar{Y}$ = the sample mean of Y

$\theta = E(\ln X)$ = the true mean of ln X.

$\tilde{\sigma}^2$ = the prior estimate of the variance of the logarithm of maintenance times

s^2 = the sample variance of in X.

Z_p = the standardized normal deviate exceeded with probability p (i. e.,

$$\int_{Z_p}^{\infty} \frac{1}{\sqrt{2\pi}} e^{\frac{-z^2}{2}} d_z = p$$

Z_α $Z_{(1-\beta)}$ = standardized normal deviate exceeded with probabilities α and (1-B) respectively.

α = the producer's risk, the probability that the equipment will be rejected when it has a true value equal to the desired value (H_o).

β = the consumer's risk; the probability that the equipment will be accepted when it has a true value equal to the maximum tolerable value (H_1)

H_o = the desired value specified in the contract or specification and is expressed as a mean, critical percentile, critical maintenance time.

H_1 = the maximum tolerable value. Note: $H_o < H_1$.

When X is a log-normally distributed random variable:

$$f(x) = \frac{1}{\sigma x \sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(\ln x - \theta)^2}, \quad 0 < x < \infty$$

If Y = in X, the probability density of Y is normal with mean θ and σ^2 variance

$$Y \sim N(\theta, \sigma^2)$$

<u>Properties of the log-normal distribution:</u>

mean = $\mu = e^{\left(\theta + \frac{\sigma^2}{2}\right)}$

variance = $\sigma^2 = e^{(2\theta + \sigma^2)}\left(e^{\sigma^2} - 1\right)$

median = $\tilde{M} = e^{\theta}$

mode = $M = e^{(\theta - \sigma^2)}$

(1-p)th percentile = $X_p = e^{(\theta + Z_p \sigma)}$

Table of standardized normal deviates:

P	Z_p
.01	2.33
.05	1.65
.10	1.28
.15	1.04
.20	.84
.30	.52

TEST ON THE MEAN

B.20 General - This test provides for the demonstration of maintainability when the requirement is stated in terms of the mean value. The test plan is subdivided into two basic procedures, identified herein as Test Plan A and Test Plan B. Test A makes use of the log-normal assumption for determining the sample size, whereas Test B does not. Both tests are fixed sample tests, (minimum sample size of 30), which employ the Central Limit Theorem and the asymptotic normality of the sample mean for their development.

B.20.1 Assumptions - Test A - Maintenance times can be adequately described by a log-normal distribution. The variance, σ^2 of the logarithms of the maintenance times is known from prior information or reasonably precise estimates can be obtained. Test B - No specific assumption concerning the distribution of maintenance times are necessary. The variance d^2 of the maintenance times is known from prior information or reasonably precise estimates can be obtained.

B.20.2 Hypotheses - H_0 Mean $= \mu_0$ (1-1)

H_1 Mean $= \mu_1, (\mu_1 > \mu_0)$ (1-2)

Illustration: $H_0 : \mu_0 = 30$ min.

$H_1 : \mu_1 = 45$ min.

B.20.3 Sample Size - For a test with producer's risk α and consumer's risk β, the sample size for Test A is given by:

$$n = \frac{(Z_\alpha \mu_0 + Z_\beta \mu_1)^2}{(\mu_1 - \mu_0)^2} \left(e^{\tilde{\sigma}^2} - 1\right) \quad (1\text{-}3)$$

where $\tilde{\sigma}^2$ is a prior estimate of the variance of the logarithm of maintenance times. The sample size for Test B is given by:

$$n = \left(\frac{Z_\alpha + Z_\beta}{\frac{\mu_1 - \mu_0}{\tilde{d}}} \right)^2 \quad (1\text{-}4)$$

where $\tilde{d}^2$ is a prior estimate of the variance of the maintenance times. Z_α and Z_β are standardized normal deviates.

B.20.4 Decision Procedure. Obtain a random sample of n maintenance times, $X_1, X_2, \ldots, X_n$, and compute the sample mean,

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \quad (1\text{-}5)$$

and the sample variance

$$\hat{d}^2 = \frac{1}{n-1}\left(\sum_{i=1}^{n} X_i^2 - n\bar{X}^2\right) \quad (1\text{-}6)$$

Test A: Accept H_0 if $\bar{X} \leq \mu_0 + Z_\alpha \frac{\hat{d}}{\sqrt{n}}$ (1-7)

Test B: Accept H_0 if $\bar{X} \leq \mu_0 + Z_\alpha \frac{\hat{d}}{\sqrt{n}}$ (1-8)

Reject H_0 otherwise.

B.20.5 Discussion - By the central limit theorem, the sample mean $\bar{X}$ is approximately normal for large n with mean E(X) and variance Var ($\bar{X}$). In Test A under the log-normal assumption Var $\bar{X} = \frac{d^2}{n}$ where $d^2 = e^{(2\theta+\tilde{\sigma}^2)}(e^{\tilde{\sigma}^2}-1) = \mu^2(e^{\tilde{\sigma}^2}-1)$ thus the sample size n can be computed using a prior estimate of $\tilde{\sigma}^2$. In Test B, a prior estimate of d^2 is assumed to be available to calculate the sample size. A critical value C is chosen such that $\mu_0 + Z_\alpha\sqrt{\text{Var}\,\bar{X}} = C = \mu_1 - Z_\beta\sqrt{\text{Var}\,\bar{X}}$. If $\mu = \mu_0$. Then $P(\bar{X}>C) = \alpha$ and if $\mu = \mu_1$, then $P(\bar{X}\leq C) = \beta$

B.20.6 Example - It is desired to test the hypothesis that the mean corrective maintenance time is equal to 30 minutes against the alternate hypothesis that the mean is 45 minutes $\alpha=\beta=.05$.

Then $H_0: \mu_0$ = 30 minutes.

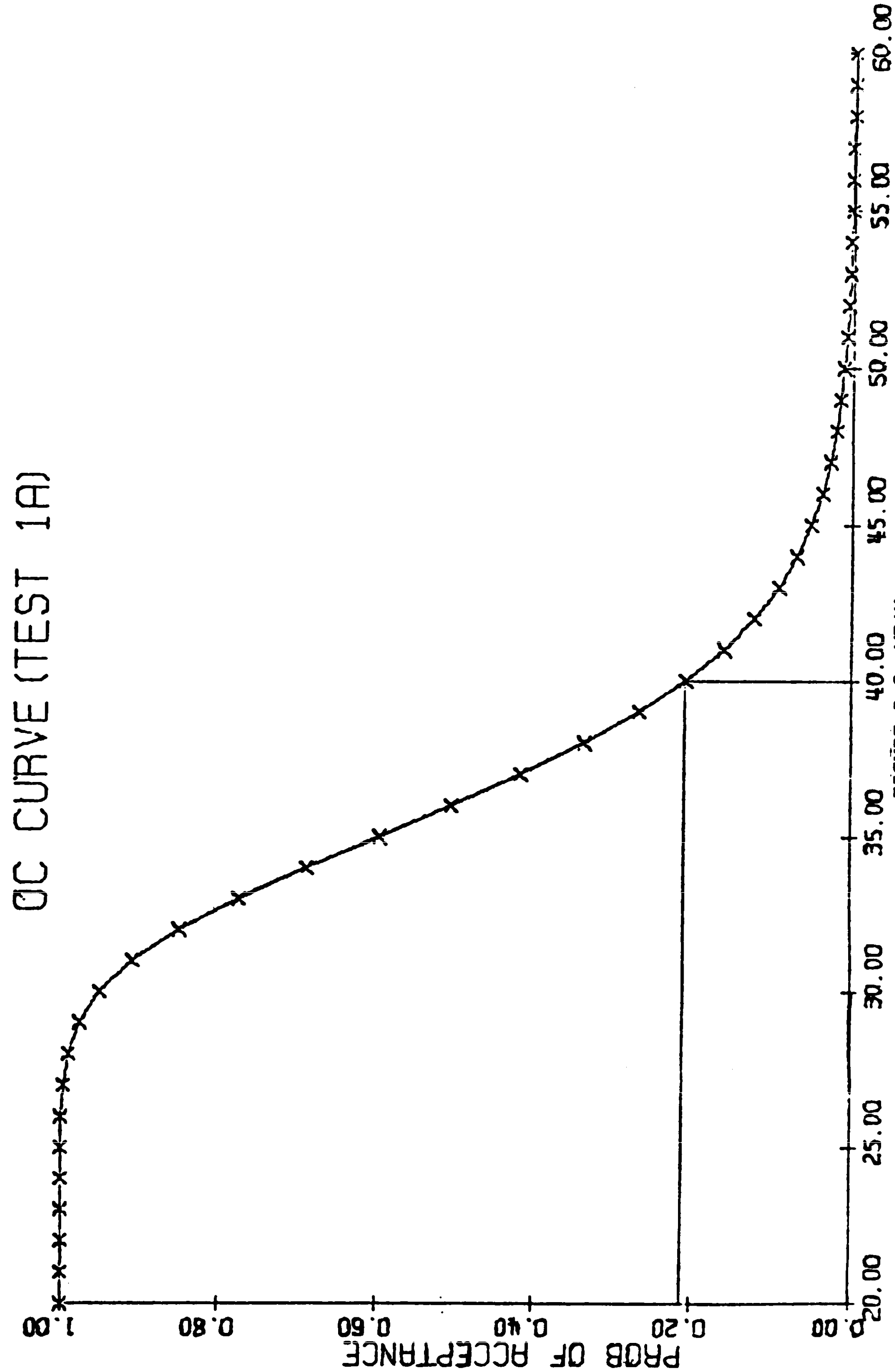
$H_1: \mu_1$ = 45 minutes.

Test A: Under the log-normal assumption with prior estimate of $\tilde{\sigma}^2 = .6$ the sample size using equation 1-3 is: $n = \frac{[1.65(30) + 1.65(45)]^2}{(45-30)^2}(e^{.6}-1) = 56$

Test B: Under the distribution-free case wiht a prior estimate of $\hat{d}^2$ = 900, (or d = 30), the sample size using eauation 1-4 is:

$$n = \left[\frac{3.29}{\left(\frac{45-30}{30}\right)}\right]^2 = 43$$

B.20.7 O.C. Curve - The OC curve for Test B for this example is given in Figure B-3. It gives the probability of acceptance for values of the mean maintenance time from 20 to 60 minutes. The OC curve for Test A for this example is given in Figure B-2. It gives the probability of acceptancd for various values of the mean maintenance time. Thus, if the true value of μ is 40 minutes, then the probability that ademonstration will end in acceptance is 0.21 as seen from Fig. B-2.


OC CURVE (TEST 1A)
PROB OF ACCEPTANCE
0.00
0.20
0.40
0.60
0.80
1.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00

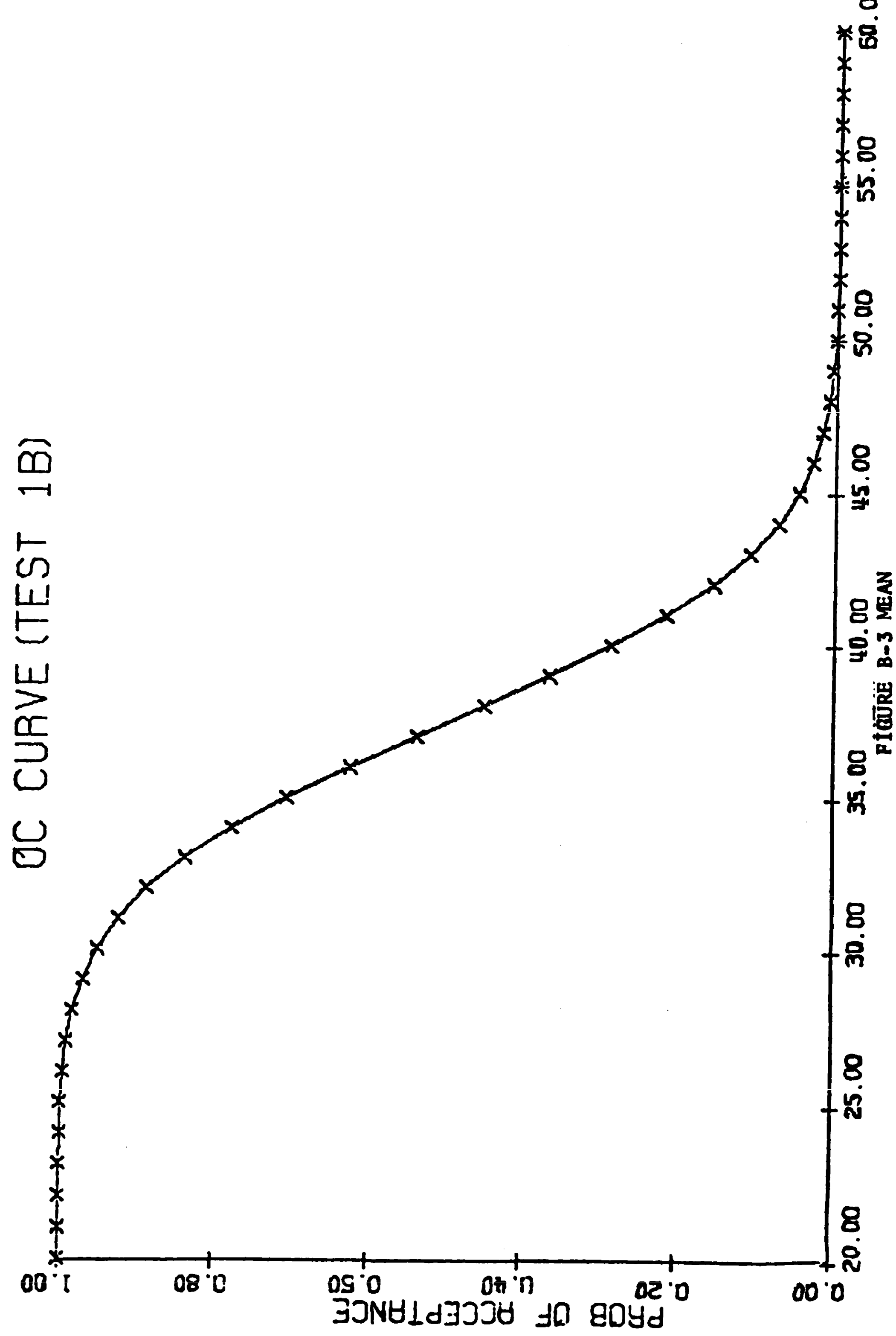

OC CURVE (TEST 1B)
PROB OF ACCEPTANCE
1.00
0.80
0.60
0.40
0.20
0.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
MEAN

FIGURE B-3

TEST METHOD 2

TEST ON CRITICAL PERCENTILE

B.30 General - This test provides for the demonstration of maintainability the requirement is stated in terms of a critical percentile value. If the critical percentile is set at 50 percent, then this test method is a test of the median. The test is a fixed sample size test. The decision criterion is based upon the asymptotic normality of the maximum likelihood estimate of the percentile value.

B.30.1 Assumption - Maintenance times can be adequately described by a log-normal distribution. The variance σ^2 of the logarithms of the maintenance times is known from prior information or reasonably precise estimates can be obtained.

B.30.2 Hypotheses - H_0: (1-p)th percentile, $X_p = T$ (2-1)

or $P[X>T_0] = p$

H_1: (1-p)th percentile, $X_p = T_1$ (2-2)

or $P[X>T_1] = p$, $(T_1 = T_0)$

Illustration: H_0: 95th percentile $= X_p = X_{.05} = 2$ hours $=$

T_0; $\ln T_1 = .4055$

H_1: 95th percentile $= X_p = X_{.05} = 2$ hours $=$

T_1: $\ln T_1 = .6932$

B.30.3 Sample Size - To meet specified α and β risks, the sample size to be used is given by the formula

$$n = \left(\frac{2 + Z_p^2}{2}\right)\tilde{\sigma}^2\left(\frac{Z_\alpha + Z_\beta}{\ln T_1 - \ln T_0}\right)^2$$ (Round up to next integer) (2-3)

where

$\tilde{\sigma}^2$ is a prior estimate of σ^2, the true variance of the logarithms of the maintenance times.

Z_p is the standardized normal deviate corresponding to the (1 - p)th percentile.

B.30.4 Decision Procedure - Compute

(2-4)

(2-5)

$$X^* = \ln T_o + Z_\alpha S\left[\frac{1}{n} + \frac{Z_p^2}{2(n-1)}\right]^{1/2} \qquad (2\text{-}6)$$

Accept H_0 if $\bar{Y} + Z_p S \leq X^*$ (2-7)

Reject H_0 otherwise.

B.30.5 Discussion - This test is based upon the fact that under the log-normal assumption, the (1-p)th percentile value is given by $X_p = e^{\theta + Z_p \sigma}$. Taking logarithms gives $\ln X_p = \theta + Z_p \sigma$, and using maximum likelihood estimates for the normal parameters θ and σ, the (1-p)th percentile maximum likelihood estimate is $\ln \hat{X}_p = \bar{Y} + Z_p S\sqrt{\frac{n-1}{n}}$. $\ln X_p$ is approximately normal. To meet the producer's and consumer's risk requirements, a critical value X^* is chosen for the sample estimate of the (1-p)th percentile X_p. Note $\bar{Y} = \hat{\theta}$ an estimate for θ.

B.30.6 Example - The following hypotheses are to be tested at $\alpha = \beta = .10$

H_0; 95th percentile = $X_{.05}$ = 1.5 hours = T_0; $\ln T_0$ = .4055

H_1; 95th percentile = $X_{.05}$ = 2.0 hours = T_1; $\ln T_1$ = .6932

A prior estimate of σ^2 is equal to 1.0 using equation 2-3.

$$n = \left(\frac{2 + (1.65)^2}{2}\right)(1)\frac{(2.56)^2}{(\ln 2.0 - \ln 1.5)^2}$$

or

$$n = 187$$

The critical value X^* is given by equation 2-5

$$X^* = \ln T_o + Z_\alpha S\left[\frac{1}{n} + \frac{Z_p^2}{2(n-1)}\right]^{1/2}$$

$$= \ln 1.5 + 1.28s\left[\frac{1}{187} + \frac{(1.65)^2}{372}\right]^{1/2}$$

or

$$X^* = .4055 + 0.1437S$$

B.30.7 OC Curve - The OC curve for Test Method 2 for this example is given in Figure B-4. It gives the probability of acceptance for various values of the 95th percentile of the maintenance time distribution. If the true value of $X_{0.05}$ is 1.7 hours, then the probability that a demonstration will end in acceptance is 0.57 as seen from Figure B-4.

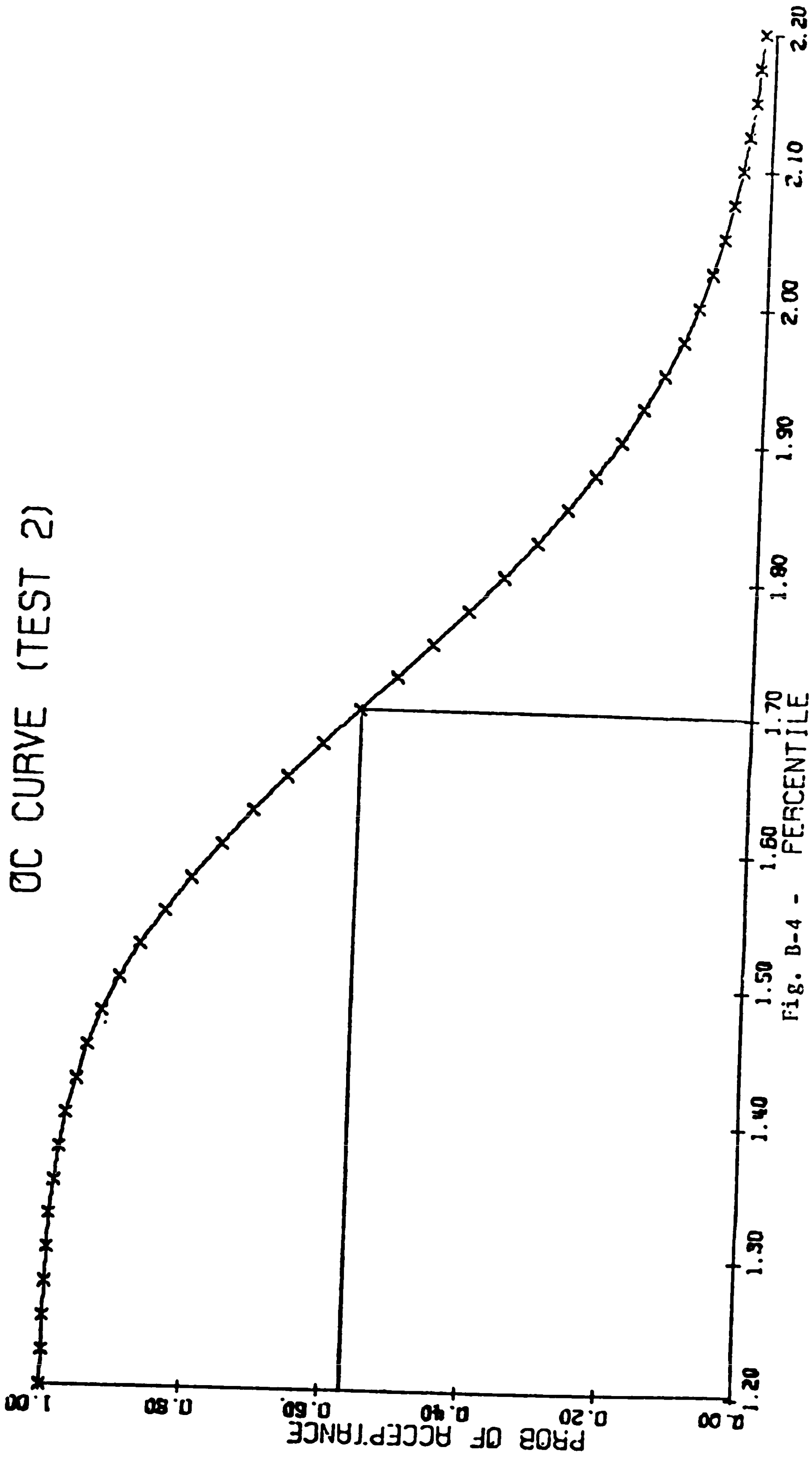

OC CURVE (TEST 2)
PROB OF ACCEPTANCE
1.00
0.80
0.60
0.40
0.20
0.00
PERCENTILE
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
2.10
2.20

Fig. B-4 -

TEST METHOD 3

TEST ON CRITICL MAINTENANCE TIME OR MANHOURS

B. 40 General - This test provides for the demonstration of maintainabilitY when the requirement is specified in terms of a critical maintenance time or critical manhours. The test is distribution-free and is applicable when it is desired to establish controls on a critical upper value on the time or manhours to perform specific maintenance tasks. In this test both the null and alternate hypothesis refer to a fixed time and the percentile varies. It is different from Test Method 2 where the percentile value remains fixed and the time varies.

B.40.1 Assumptions - No specific assumption is necessary concerning the distribution of maintenance time or manhours.

B.40.2 Hypothesis - $H_0: \; T = X_{p_o}$ (3-1)

$(P_1 > P_o)$

$H_1: \; T = X_{p_1}$ (3-2)

For specified α and β:

Illustration - $H_0: \; 30 \text{ min.} = X_{0.50}$ = 50th percentile (median)

$H_1: \; 30 \text{ min.} = X_{0.75}$ = 25th percentile

B.40.3 Sample Size, n, and Acceptance Number, c - The normal approximation to the binomial distribution is employed to find n and c when p_0 is not a small value. Othherwise, the Poisson approximation is employed. The equations for n and c are as follows:

For $0.20 \leq p_0 \leq 0.80$

$$n = \left[\frac{Z_\beta\sqrt{P_1 q_1} + Z_\alpha\sqrt{P_o q_o}}{P_1 - P_o}\right]^2$$ (Use next higher integer value.) (3-3)

$$n \left[\frac{Z_\beta P_o\sqrt{P_1 q_1} + Z_\alpha P_1\sqrt{P_o q_o}}{Z_\alpha\sqrt{P_o q_o} + Z_\beta\sqrt{P_1 q_1}}\right]$$ (Use next lower integer value.) (3-4)

For $p_0 < 0.20$

For this case n and c can be found from the following two equations:

$$\sum_{r=0}^{c} \frac{e^{-np_0}\,(np_0)^r}{r!} \geq 1-\alpha \qquad (3\text{-}5)$$

$$\sum_{r=0}^{c} \frac{e^{-np_1}\,(np_1)^r}{r!} \leq \beta \qquad (3\text{-}6)$$

Table B-I provides sampling plans for various α and β risks and ratios p_1/p_0 when $p_0 < 0.20$.

B.40.4 Decision Procedure. Random samples of maintenance times are taken, yielding n observations $X_1, X_2, \ldots, X_n$. The number of such observations exceeding the specified time T is counted. This number is called r.

Accept H_0 if $r \leq c$. (3-7)

Reject H_0 if $r > c$. (3-8)

B.40.5 Discussion. In the development of the decision criteria and sample size, equations for this test, the normal or Poisson approximation to the binomial distribution is used.

B.40.6 Example. A median value of 30 minutes is considered acceptable whereas if 30 minutes is the 25th percentile then this is considered unacceptable. The following hypotheses result: ($\alpha = \beta = .10$)

H_0: 30 minutes = $X_{0.50}$ = 50th percentile median

H_0: 30 minutes = $X_{0.75}$ = 25th percentile

Then $Z_\alpha = Z_\beta = 1.28$, $p_0 = .50$, $p_1 = .75$ using equations 3-3 & 3-4.

$$n = (1.28)^2 \left[\frac{\sqrt{(.75)(.25)} + \sqrt{(.50)(.50)}}{(.25)}\right]^2 \approx 23$$

and,

$$c = 23 \left[\frac{\frac{(1.28).5}{1.28}\sqrt{(.75)(.25)} + 1.28\,(.75)\sqrt{(.50)\,(.50)}}{\sqrt{(.50)(.50)} + 1.28\sqrt{(.75)(.25)}}\right] \approx 14$$

B.40.7 OC Curve - The OC curve for Test Method 3 for this example is given in Figure B-5. It gives the probability of acceptance for values of probability p, varying from 0.3 to 1.0. Here X_p is (1-p) th percentile. Thus, if the true value of the given critical maintenance time is 40th percentile, i.e., if the true value of the given critical maintenance time is 40th demonstration will end in acceptance is 0.61 as seen from Fig. B-5.

SAMPLING PLANS FOR SPECIFIED p_0, p_1, α, and β
WHEN p_0 IS SMALL (e.g., $p_0 < 0.20$)

$k = \frac{p_1}{p_0}$	$\alpha = 0.05$						$\alpha = 0.10$						$\alpha = 0.20$					
	$\beta = 0.05$		$\beta = 0.10$		$\beta = 0.20$		$\beta = 0.05$		$\beta = 0.10$		$\beta = 0.20$		$\beta = 0.05$		$\beta = 0.10$		$\beta = 0.20$	
	c	D	c	D	c	D	c	D	c	D	c	D	c	D	c	D	c	D
1.5	66	54.1	54	43.4	39	30.2	51	43.0	40	33.0	29	23.2	36	31.8	27	23.5	17	14.4
2	22	15.7	18	12.4	14	9.25	17	12.8	14	10.3	10	7.02	12	9.91	9	7.29	6	4.73
2.5	13	8.46	10	6.17	8	4.70	10	7.02	8	5.43	6	3.90	7	5.58	5	3.34	3	2.30
3	9	5.43	7	3.98	6	3.29	7	4.66	5	3.15	4	2.43	4	3.09	3	2.30	2	1.54
4	6	3.29	5	2.51	4	1.97	4	2.43	3	1.75	2	1.10	3	2.30	2	1.54	1	0.824
5	4	1.97	3	1.37	3	1.37	3	1.75	2	1.10	2	1.10	2	1.54	1	0.824	1	0.824
10	2	0.818	2	0.818	1	0.353	1	0.532	1	0.532	1	0.532	1	0.824	1	0.824	0	0.227

To find the sample size n, for given p_0, p_1, α, and β, divide the appropriate D value by p_0 and use the greatest integer less than the quotient. Example: $p_0 = 0.05$, $p_1 = 0.20$, $\alpha = 0.10$, $\beta = 0.05$, and $k = \frac{0.20}{0.05} = 4$. Then $n = \frac{D}{0.05} = \frac{2.43}{0.05} = 48$. The acceptance number is $c = 4$.

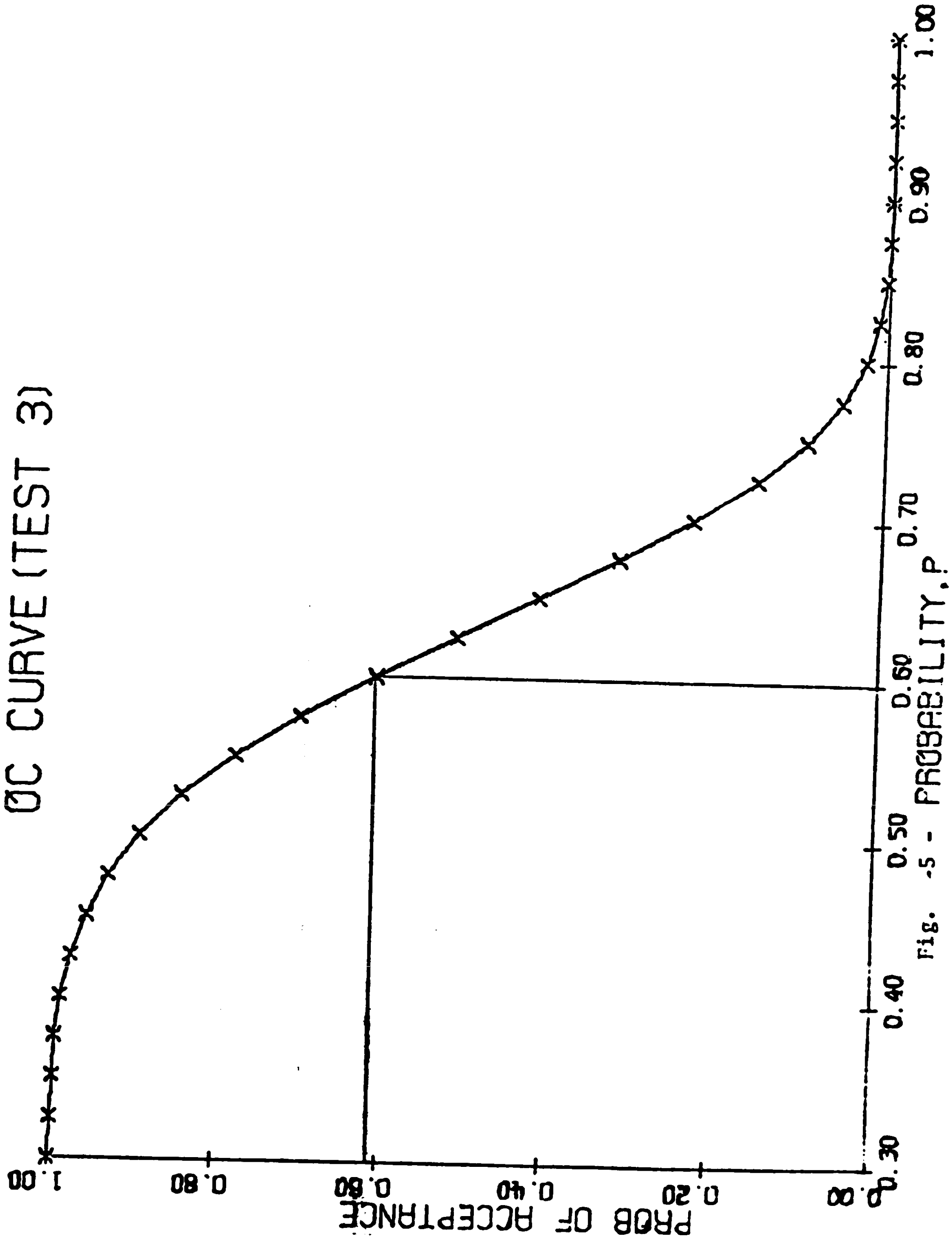

OC CURVE (TEST 3)
PROB OF ACCEPTANCE
1.00
0.80
0.60
0.40
0.20
0.00
PROBABILITY, P
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

Fig. -5 -

TEST METHOD 4

TEST ON THE MEDIAN (ERT)

B.50 General - This method provides for demonstration of maintainabilitY the requirement is stated in terms of an equipment repair time (ERT) median, which will be specified in the detailed equipment specification.

B.50.1 Assumption - This method assumes the underlying distribution of corrective maintenance task times is lognormal.

B.50.2 Sample Size - The sample size required is 20. This sample size must be used to employ the equation described in this test method.

B.50.3 Task Selection and Performance - Sample tasks shall be selected in accordance with the procedure outlined in Appendix "A". The duration of each shall be recorded and used to compute the following statistics:

$$\log MTTR_G = \frac{\sum_{i=1}^{N_c} (\log M_{ct(i)})}{N_c} \qquad (4\text{-}1)$$

$$S = \sqrt{\sum_{i=1}^{N_c} \frac{(\log M_{ct(i)})^2}{N_c} - (\log MTTR_G)^2} \qquad (4\text{-}2)$$

Where: $MTTR_G$ is the measured geometric mean time to repair. It is the equivalent to the $\bar{M}ct$ used in other plans included in this document.

B.50.4 Decision Procedure - The equipment under test will be considered to have met the maintainability requirement (ERT) when the measured geometric mean-time-to-repair ($MTTR_G$) and standard deviation(S) as determined in 50.3 satisfies the following expression:

$$\text{Accept if } \log MTTR_G \leq \log ERT + .397(S) \qquad (4\text{-}3)$$

where: log ERT = logarithm of the equipment repair time
log $MTTR_G$ = the value determined in accordance with para. 50.3
S = the value determined in accordance with para. 50.3

B.50.5 Discussion - The value of equipment repair time (ERT) to be specified in the detailed equipment specification should be determined using the following expression:

$$ERT \text{ (specified)} = 0.37\ ERT_{max} \qquad (4\text{-}4)$$

where:

ERT_{max} = the maximum value of ERT that should be accepted no more than 10 percent of the time.

0.37 = a value resulting from application of "student's t" operating characteristics that assures a 95 percent probability that an equipment having an acceptable ERT will not be rejected as a result of the maintainability test when the sample size is 20, and assuming a population standard deviation (σ) of 0.55.

B.50.5.1 <u>Derivation of Criteria</u> - The following are brief explanations of the derivations of various criteria specified herein, and are intended for information purposes only. The acceptance criterion, log MTTR $\leq$ log ERT $\neq$ 0.397(S), assures a probability of .95 of accepting an equipment or systems as a result of one test when the true geometric mean-time-to-reptir is equal to the specified equipment repair time (that is, a probability of 0.05 of rejecting an equipment or systems having a true $MTTR_G$ equal to the specified ERT). This was derived by using conventional methods for establishing acceptance criteria. The The conventional methods for establishing acceptance based on the measured mean of a small sample, (that is, sample size less than 30), and when the true standard deviation (σ) of the population can only be estimated, is to compare the measured mean with the desired mean using the expression:

$$t = \frac{(\bar{x} - \bar{x}_o)}{S} \sqrt{N_c - 1}$$

$$S = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{N_c}}$$ or the standard deviation of the sample;

$\bar{x}$ = the sample or measured mean

$\bar{x}_o$ = the specified or desired mean

N_c = the sample size

x_i = the value of one measurement of the sample

The decision to accept the product will be made when the test results give a value of t, as calculated from the above expression numerically less than or equal *to* a value of t obtained from "student's t" distribution tables at the established level (that is, 0.99, 0.95, 0.90, and so forth) of acceptance and the appropriate sample size. The "student's t" distribution tables (for a single tailed area) give a value of t = 1.729 at tje 0.95acceptance level when the sample size is 20 (that is, 19 degrees of freedom). The tabel for single tailed area is used since only values of $MTTR_G$ greater than the specified ERT are critical. An equipment with any value of $MTTR_G$ lower than the specified ERT is acceptable. expression for "t" to the maintainability test, let $\bar{x}_0$ = log ERT (specified), $\bar{x}$ = log MTTR (measured), S = the measured standard deviation of the logarithms of the sample of measured repair time, and N = the sample size of 20. The measured $MTTR_G$ is then compared with the desired ERT by calculating the valur of t using the expression below:

$$t = \frac{(\log MTTR_G - \log ERT)}{S} \sqrt{19}$$

The equipment under test can be acceptable if the value of t calculated from the expression above is equal to or less than + 1.729 (the value of t from the "student's t" distribution tables at an acceptable level or .95 when the sample size is 20). Therefore, the equipment should be accepted when:

$$\sqrt{19}\ \frac{(\log MTTR_G - \log ERT)}{S} \leq +\ 1.729$$

Upon rearranging and simplifying this expression, the acceptance criterion is obtained as shown below:

$$\log MTTR_G - \log ERT \leq \frac{1.729\,(S)}{\sqrt{19}}$$

$$\log MTTR_G \leq \log ERT + .397\ (S)$$

(NOTE: Reference - "Introduction to Mathematical Statistics," P. Heel, J. Wiley and Sons, Inc., 2nd Edition, 1954, PP222-229)

TEST METHOD 5

TEST ON CHARGEABLE MAINTENANCE DOWNTIME PER FLIGHT

B.60 General - Because of the relatively small size of the demonstration fleet of aircraft and administrative and operational differences between it and fully operational units, operational ready rate or availability cannot be demonstrated directly. However, a contractual requirement for chargable downtime per flight can be derived analytically from an operational requirement of operational ready rate or availability. This chargeable downtime per flight can be thought of as the allowable time (hours) for performing maintenance given that the aircraft has levied on it a certain availability or operational readiness requirement. The requirement for chargeable downtim per flight will be established using the procedure in B.60.3. Chargeable downtime per flight can then be demonstrated using the procedures in B.60.5.

B.60.1 Definitions - The following definitions apply to this test method:

A = Availability - A measure of the degree (expressed as a probability) to which an aircraft is in the operable and committable state at the start of the mission, when the mission is called for at an unknown (random) point in time. In this standard, availability is considered synonymous with operational readiness. The aircraft is not considered to be in an operable and committable state when it is being serviced and is undergoing maintenance (see MIL-STD-721B].

TOT = Total Active Time in Hours.

Active Time = That time during which an aircraft is assigned to an organization for the purpose of performing the organizational mission. It is time during which:

1. The aircraft is flying or ready to fly.
2. Maintenance is being performed.
3. Maintenance is delayed for supply or administrative reasons.

DUR +* Daily Utilization Rate - The number of flying hours per day.

AFL = Average Flight Length - Flying hours per flight.

NOF = Number of Flights per Day.

DT = Time (in hours) during which the aircraft is not ready to commence an assigned mission (i.e., have the flight crew board the aircraft).

CMDT = Chargeable Maintenance Downtime - Time (in hours) during which maintenance personnel are working on the aircraft, except when the only work being done would fall under the nonchargeable maintenance downtime (NCMDT) category.

NCMDT = Nonchargeable Maintenance Downtime - Time (in hours) during which the aircraft is not available for immediate flight but the only maintenance being performed is not chargeable. It would include the following:

1. To correct maintenance or operational errors not attributable to technical orders, contractor furnished training or faulty design.

2. Miscellaneous tasks such as keeping of records or taxiing or towing the aircraft to or from other than the work center area.

3. Repair of accident or battle damage.

4. Modification tasks.

5. Maintenance caused by test instrumentation,

DDT = Delay Downtime - Downtime (in hours) during which maintenance is required but no maintenance is being performed on the aircraft for supply or administrative reasons. It would include the following:

1. Supply Delay Downtime.

   a. Not Operationally Ready Supply (NORS) time.

   b. Item obtainment time from other than the work center are a.

2. Administrative Delay Downtime.

   a. Personal breaks such as coffee or lunch.

   b. No maintenance people available for administrative reasons.

α = the producer's risk: The risk that the producer (contractor) must take that the hypothesis that a true mean = M_Θ will be rejected even though it is true. The desirable value of α must be determined by judgement and agreed upon by the procuring activity and the contractor. All other things being equal, a smaller value of α will require a larger sample size.

M = The maximum mean chargeable maintenance downtime per flight.

M_Θ = The required mean CMDT per flight.

$M-M_\Theta$ = The difference between the maximum mean (M) of the parameter being tested and the specified mean (M_Θ). This value must be determined in conjunction with a value for β, the consumer's risk. M is a value, greater [worse) than the specified mean, which the consumer is willing to accept, but only with a small risk or probability (β). If the true mean is in fact equal to the value of M selected, the hypothesis the true mean = M_Θ will be accepted, although erroneously, 100 β percent of the time.

β = the consumer's risk. The risk, which the consumer is willing to take, of accepting the hypothesis that the true mean = M_Θ when in fact the true mean = M. All other things being equal, a smaller value of β will require a larger sample size.

σ = the true standard deviation of the parameter (CMDT per flight) being tested. This value, unless it is a specification requirement, will not be known, but an estimate must be made. (It is assumed that both M and M_Θ will have the same value of σ .)The contractor's maintainability math model, previous models, or previous data may be used. All other things being equal a larger value of β will require a larger sample size.

B.60.2 Assumptions - This method requires no assumption as to the probability distribution of chargeable downtime per flight. The method is valid only if the Central Limit Theorem applies, which means that the sample size (number of flights) must be large enough for this theorem to apply. The sample size shall be at least SO, but the actual size is to be determined in accordance with para. B.60.4.

B.60.3 Derivation of CMDT per Flight from Availability.- The requirement for CMDT per flight whichwill be demonstrated will be determined using the following mathematical derivation.

$$A = 1 - \frac{CMDT + NCMDT + DDT}{TOT} \qquad (5\text{-}1)$$

$$A(TOT) = TOT - CMDT - NCMDT - DDT \qquad (5\text{-}2)$$

$$CMDT = TOT - A(TOT) - NCMDT - DDT \qquad (5\text{-}3)$$

$$\frac{CMDT}{NOF} = \frac{TOT - A(TOT) - NCMDT - DDT}{NOF} \qquad (5\text{-}4)$$

but,

$$NOF = \frac{TOT\ (DUR)}{24\ (AFL)} \qquad (5\text{-}5)$$

therefore,

$$\frac{CMDT}{NOF} = \frac{24\ (AFL)}{DUR} - \frac{A(24)(AFL)}{DUR} - \frac{NCMDT}{NOF} - \frac{DDT}{NOF} \qquad (5\text{-}6)$$

$\frac{CMDT}{NOF}$ = CMDT per flight, which will be demonstrated.

Values for UR and AFL should be those planned for the aircraft during operational use. Values for $\frac{CMDT}{NOF}$ and $\frac{DDT}{NOF}$ are a function of the operational environment. They will be provided to the contractor in the RFP or, if not, will be provided by him in his proposal. The value for availability or operational ready rate will be provided in the RFP.

Example: Follwing is an example of how a requirement for CMDT per flight $\frac{CMDT}{NOF}$ will be derived:

Required A = 0.75

DUR = 2 hours per day

AFL = 4 hours per flight

$\frac{NCMDT}{NOF}$ = 0.2 hours per flight

$\frac{DDT}{NOF}$ = 1.0 hours per flight

Then,

$$\frac{CMDT}{NOF} = \frac{24(4)}{2} - \frac{(0.75)(24)(4)}{2} - 0.2 - 1.0$$

$$\frac{CMDT}{NOF} = 48 - 36 - 0.2 - 1.0$$

$$\frac{CMDT}{NOF} = 10.8 \text{ hours per flight}$$

B.60.4 Sample Size - Since the Central Limit Theorem is applied, the expected distribution of the means will take on a normal distribution as in Figure B-6. If the true mean is equal to M_Θ and a particular α is desired the upper distribution (the mean of the distribution will equal M_Θ) will apply. It is on this basis that an acceptance rule is generated to the effect that if $\bar{X}$ is found to be equal to or less than the value $M_\Theta + \frac{Z_\alpha \sigma}{\sqrt{n}}$ the item is to be accepted.

If the true mean is equal to M (which is greater than M_Θ) the distribution of means will take on a normal distribution with a mean of M as shown in the lower distribution, The value to be used as an acceptance criterion $M_\Theta + \frac{Z_\alpha \sigma}{\sqrt{n}}$ corresponds and is equal to a value:

$\left(M + \frac{Z_{\alpha'} \sigma}{\sqrt{n}}\right)$ Where α' is a new confidence level

$$M_\Theta + \frac{Z_\alpha \sigma}{\sqrt{n}} = M + \frac{Z_{\alpha'} \sigma}{\sqrt{n}}$$

where $M = M_\Theta + (M - M_\Theta)$ (5-8)

$$M_\Theta + \frac{Z_\alpha \sigma}{\sqrt{n}} = M_\Theta + M - M_\Theta + \frac{Z_{\alpha'} \sigma}{\sqrt{n}} \quad (5\text{-}9)$$

or simplifying, the sample size (n) requirement is:

$$n = \frac{(Z_\alpha - Z_{\alpha'})^2}{\left(\frac{M - M_\Theta}{\sigma}\right)^2} = \frac{(Z_\alpha - Z_{(1-\beta)})^2}{\left(\frac{M - M_\Theta}{\sigma}\right)^2} \quad (5\text{-}10)$$

If this expression should result in n less than 50, then a sample of 50 shall be used.

α = Prob. of rejection if true mean equals M.

$1 - \alpha' = \beta$ = Prob. of acceptance if true mean equals M.

Z_α, $Z_{(1-\beta)}$ = standardized normal deviated as defined.

See table below for relationships between Zw and α & β

$w = \alpha$ or $1-\beta$

Z_w	.01	.05	.1	.15	.2	.3	.7	.8	.85	.9	.95	.99
	2.33	1.65	1.28	1.04	.84	.52	-.52	-.84	-1.04	-1.28	-1.65	-2.33

$Z_w = Z_\alpha$ or $Z_{(1-\beta)}$

Example: Suppose for a requirement of M_Θ = 2.0, the following statistical test parameters were agree to by the procuring activity and the contractor:

$\alpha = 0.10$; $Z_\alpha = 1.28$; $\beta = 0.10$; $Z_{1-\beta} = -1.28$; $M-M_o = 0.30$; $\sigma = 1.0$;

$$\frac{M-M_o}{\sigma} = 0.3$$

Using equation 5-10:

$$n = \frac{(1.28 + 1.28)^2}{(.3)^2} = \frac{(2.56)^2}{(.3)^2} = \frac{6.57}{.09} = 73$$

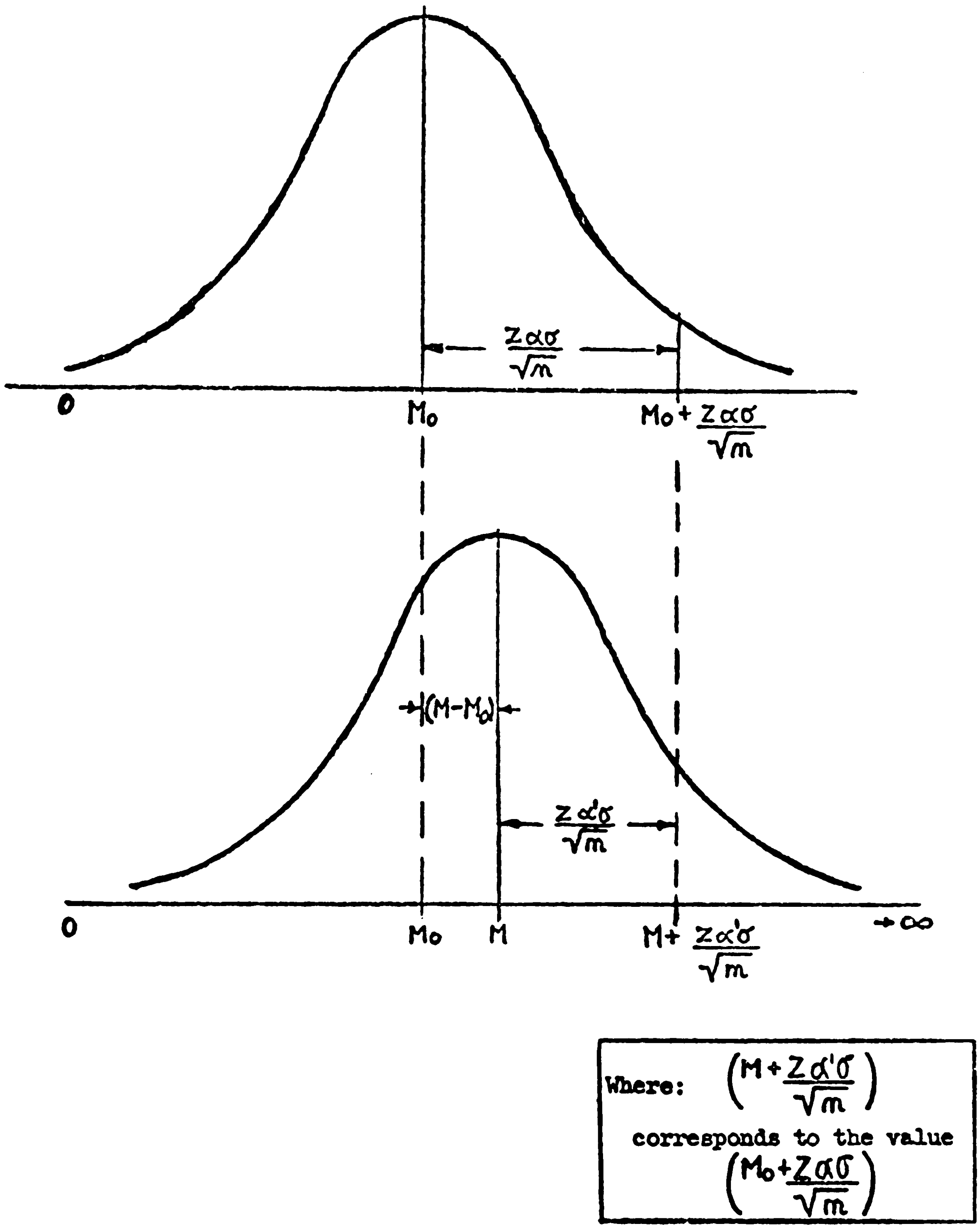


Fig. B-6 Distribution of Means

B.60.5 Decision Procedure - The chargeable maintenance downtime (X_i) after each flight will be measured and, at the end of the test, the total chargeable downtime will be divided by the total number of flights to obtain ($\overline{X}$) the sample mean CMDT and the sample standard deviation (s) of CMDT.

$$\overline{X} = \frac{\sum_{i=1}^{NOF} X_i}{NOF} \tag{5-11}$$

$$s = \sqrt{\sum_{i=1}^{NOF} \frac{(X_i - \overline{X})^2}{NOF-1}} = \sqrt{\frac{1}{(NOF-1)} \sum_{i=1}^{NOF} X_i^2 - (NOF)\overline{X}^2} \tag{5-12}$$

Accept if: $\overline{X} \leq M_o + \frac{Z_\alpha S}{\sqrt{NOF}}$ (5-13)

Reject if: $\overline{X} > M_o + \frac{Z_\alpha S}{\sqrt{NOF}}$ (5-14)

TEST METHOD 6

TEST ON MANHOIJR RATE

B.70 General - This test for demonstrating manhour rate (manhours per flight hour)is based on a determination during Phase II test operation of the total accumulative chargeable maintenance manhours and the total accumulative demonstration flight hours. The demonstrated manhour rate is calculated as:

$$\text{Manhour Rate} = \frac{\text{Total Chargeable Maintenance Manhours}}{\text{Total Demonstration Flight Hours}} \qquad (6\text{-}1)$$

If the demonstrated manhour rate is less than or equal to the manhour rate requirement plus a maximum value (ΔMR), by which the demonstrated manhour rate will be permitted to differ from the required manhour rate, then the requirement has been met. ΔMR will be provided, by the procuring activity, as a percentage of the system manhour rate requirement and will be determined based upon such considerations as the expected Phase II duration, and prior experience with similar systems. It is recognized that this demonstration method is nonstatistical in nature and does not allow the determination of quantitative producer's and consumer's risk levels. It is for this reason that the ΔMR is provided (in a subjective manner] to minimize the producer's risk,

B.70.1 Normally, all maintenance performed by approved test maintenance personnel during Phase II and documented in appropriate maintenance reports will be the source of data for identifying chargeable maintenance manhours. The procuring activity may elect to terminate the demonstration prior to Phase II completion if sufficient data are collected to project that the requirement will be met.

B.70.2 The manhour rate requirement must pertain to the aircraft configuration provided for in the contract. For Phase II flights conducted with a configuration other than this, an appropriate amount of chargeable manhours will be included in calculating the total chargeable manhours. This amount will be based upon the predicted manhour rate associated with the equipment not installed.

B.70.3 Care must be exercised in assuring that the predicted manhour rate pertains to flight time and not equipment operating time. The contractor must develop appropriate ratios of equipment operating time to flight time.

TEST METHOD 7

TEST ON MANHOUR RATE - (USING SIMULATED FAULTS)

B.80 General. This test for demonstrating manhour rate (manhours per operating hour) is based on (a) the predicted total failure rate of the equipment used in the formulation of Table I, Appendix A, (b) the total accumulative chargeable maintenance manhours and the total accumulative simulated demonstration operating hours. The demonstrated manhour rate is calculated as:

$$\text{Manhour Rate} = \frac{\text{Total Chargeable Maintenance Hours}}{\text{Total Operating Time}} = \frac{\sum_{i=1}^{n} X_{ci} + (PS)}{T} \qquad (7\text{-}1)$$

where:

X_{ci} = Manhours for corrective maintenance task i

n = Number of corrective maintenance tasks sampled, n shall not be less than 30

MTBF = MTBF of the unit (value used in development of Table I)

(PS) = Estimated average total manhours which would be required for preventive maintenance during a period of operating time equal to n (MTBF) hours

$\sum_{i=1}^{n} \frac{X_{ci}}{n} = \bar{X}_c$ = Average number of corrective maintenance manhours per corrective maintenance task

T = operating time

B.80.1 Discussion. When maintenance tasks are simulated as in Table 1, $T \approx n \cdot$(MTBF) where $\frac{1}{MTBF}$ the total failure rate of the equipment in question.

$$\frac{\sum_{i=1}^{n} X_{ci} + (PS)}{T} = \frac{\sum_{i=1}^{n} X_{ci} + (PS)}{n \cdot (MTBF)} = \frac{1}{MTBF}\left[\bar{X}_c + \frac{(PS)}{n}\right] \qquad (7\text{-}2)$$

All co orients of (7-2) with the exception of $\bar{X}_c$ can be considered constants. $\bar{X}_c$ can be considered a normally distributed variable when n is large (due to the Central Limit Theorem) with Variance = $\frac{\bar{d}^2}{n}$.

If $\bar{X}_c$ is normally distributed it can be shown that the function:

$\frac{1}{(MTBF)} [\bar{X}_c + \frac{PS}{n}]$ is also normally distributed around the mean of the manpower rate with Variance + $(\frac{1}{n}) (\frac{d}{MTBF})^2$; assuming $d = \hat{d}$.

B.80.2 Decisiojn Procedure. Therefore, if the manhour rate requirement = μR,

Accept if:

$$\bar{\bar{X}}_c \leq \psi_R \text{ (MTBF)} - (\frac{PS}{n}) + Z_\alpha \frac{\hat{d}}{n} \quad (7\text{-}3)$$

Where α denotes producer's risk.

✩ US. GOVERNMENT PRINTNG OFFICE: 1977-703-020:1025

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

OMB Approval No. 22-R255

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DOCUMENT IDENTIFIER AND TITLE

NAME OF ORGANIZATION AND ADDRESS	CONTRACT NUMBER
	MATERIAL PROCURED UNDER A ☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE DOCUMENT CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?
   A. GIVE PARAGRAPH NUMBER AND WORDING.

   B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES

2. COMMENTS ON ANY DOCUMENT REQUIREMENT CONSIDERED TOO RIGID

3. IS THE DOCUMENT RESTRICTIVE?

   ☐ YES ☐ NO *(If "Yes", in what way?)*

4. REMARKS

SUBMITTED BY *(Printed or typed name and address - Optional)*	TELEPHONE NO.
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