US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP-702-105
*Test Operations Procedure (TOP) 6-2-335 30 May 1985
AD No.

TEST, MEASUREMENT, AND DIAGNOSTIC EQUIPMENT (SYSTEM PECULIAR)

1. SCOPE. This (TOP) provides guidance for planning tests of system-peculiar test, measurement, and diagnostic equipment (TMDE) including Test Program Sets (TPS) needed to support a system, to ensure its conformance with requirements documents, Acquisition Plan (AP), Test Program Set Management Plan (TPSMP), and Item Integrated Logistics Support Plan (ILSP). Subtests to satisfy the requirements for the particular TMDE and test type (DT II and III) can be selected or supplemented from those listed in the test procedures. Originator Supplied

2. FACILITIES AND INSTRUMENTATION. Facilities and instrumentation are covered in TOP's and other referenced documents.

3. REQUIRED TEST CONDITIONS.

3.1 Test Planning. The test planner must be thoroughly familiar with the stated Army requirements for the end item as stated in the applicable requirements documents (AP, TPSMP, ILSP), engineering design handbooks, and other technical documents. He must also be familiar with the characteristics of the planned interface between the TMDE and the end item and the other elements of the maintenance support planned for the end item through intermediate support level maintenance.

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The maintenance level(s) where the TMDE is to be employed and the particular conditions of extreme operating and storage environments planned for the TMDE must be known. The testing of system-peculiar TMDE may be planned in the test plan for the overall system (i.e., the end item and all its supporting equipment) or separated from the end item and treated in a separate test plan.

The testing of system-peculiar TMDE as a part of an overall system test should be readily identifiable. For example, the TMDE testing may be organized as part B of section II of the detailed test plan (part A would comprise the end item subtests), the TMDE testing may be included as subelements of one or more of the required end-item subtests, or some other technique may be used that is within the guidance of TECR 70-24.[1] The test plan should include background information and methodology relative to the TMDE in the following areas:

a. The description of materiel should identify and describe the requirements and major characteristics of the planned system-peculiar TMDE to be employed through intermediate support level. The technical aspects of the ILSP/TPSMP for the supported end item and the system-peculiar TMDE should also be summarized through the intermediate support level.

b. When documenting testing and criteria, the test planner should consider not only criteria sources such as requirements documents (AP, AR) and the test directive (IEP/TDP) but also statements in the ILSP/TPSMP that are considered to be applicable to the planned test. Emphasis should be placed on specific performance requirements for the TMDE, such as the probabilities that (1) an operational item will actually be indicated as operational, (2) a defective item will actually be indicated as defective, (3) the faulty item requiring repair action will be correctly identified, and (4) correct repair instructions will be provided.

c. Systematic test methodology should be developed to determine the necessity and adequacy of the TMDE performance for all the required maintenance tasks through intermediate support level.

d. Test methodology should be developed to determine the adequacy of the TMDE to meet the full range of environmental requirements applicable to its operation and storage. In many instances the TMDE requirements will differ from the supported system.

e. Test methodology should be developed to determine the adequacy of the TMDE to meet other test requirements for initial inspection, physical characteristics, safety, reliability, and maintainability.

3.2 Initial Inspection.

a. Review literature pertinent to the TMDE, including its system support package and other end item support equipment essential to a TMDE evaluation for familiarization with performance requirements, operational characteristics, the functions of components, and the results of previous tests. The literature includes the approved detailed test plan, drawings, draft and final equipment publications, the safety statement, and reports and evaluations of previous tests.

[1] Numbers match those in Appendix D, References.

b. Inspect the end item and the TMDE, including its system support package, for damage. (See TOP 1-2-504.[2]) If damaged, investigate as to cause; report by EPR, and correct before the start of the test.

c. Inventory the TMDE, including its system support package, for completeness. If the complete TMDE has not been received (in accordance with AMCR 700-15[3]), forward a teletype EPR to the test sponsor and other agencies in accordance with AMCR 70-13[4] and TECOM supplement thereto. In this event, do not commence tests until either the missing support items arrive or a waiver is furnished.

4. TEST PROCEDURES. Conduct performance tests to determine whether the system-peculiar TMDE is necessary and adequate to support the end item in accordance with the requirements documents (AP, ILSP, TPSMP). The tests may include a theoretical engineering study of one or more characteristics of the TMDE to provide supplemental data when actual hardware tests must be unduly limited for some reason.

4.1 Supporting Tests. Applicable TOP's, military standards, and other documents, and the tests (in preferred order of completion with respect to high risk, short duration) to be considered in formulating the detailed test plan are listed below. The tests are written to provide broad guidance for planning the test of a specific TMDE design. It may be necessary to incorporate additional tests, modify some of the methods outlined, or consult other TOP's. Whether or not separate test plans are used, the test of the TMDE will, when possible, be planned to be concurrent with the test of the end item, and where practicable, subtests (e.g., salt fog test) will be conducted together. Test planning is discussed in paragraph 3.1.

4.2 Self-check Test.

a. Method.

(1) Subject the TMDE to its specified self-checks and other technical manual preoperational checks to determine whether it will meet its own criteria.

(2) Verify self-check validity by comparing self-check results with results obtained from using independent instrumentation when the unit is operational and when potential faults are introduced.

(3) See paragraph 4.5 for a technique for introducing faults.

b. Data required.

(1) Criteria met and/or not met.

(2) Introduced faults recognized and/or not recognized.

(3) Major discrepancies or variations between self-check results and operational results.

4.3 Purchase Description/Specification Tests.

a. Method.

(1) Subject the TMDE to specification performance tests to ensure that it is operating within prescribed limits and that it is a valid sample for evaluation.

(2) Compare measured parameters with specified values.

(3) Verify go/no-go indicators by using specified go/no-go signals and marginal signals.

b. Data required.

(1) Operations according to specifications and/or failures to operate according to specifications.

(2) Major discrepancies or variations between specified values and measured parameters.

(3) Proper operation and/or failure of go/no-go indicators, specified go/no-go signals, and marginal signals.

4.4 Operational Equipment Tests.

a. Method.

(1) Test the TMDE to determine whether it will indicate that an operational system is operational (i.e., not indicate faults where none exist).

(2) In this test, check the system parameters with independent instrumentation to ensure that it is within purchase description requirements.

(3) Then check the "calibrated" system with the TMDE and note any discrepancies.

b. Data required.

(1) Operational failures or faults indicated that did not exist.

(2) Parameters within and not within purchase description requirements.

(3) Any discrepancies between the TMDE and the "calibrated" system.

4.5 Potential Fault Detection and Isolation Test.

a. Method.

(1) Test the TMDE to determine whether it can detect and isolate faults as appropriate and as required by the requirements documents (AP, ILSP, TPSMP, etc.).

(2) Identify potential faults for insertion into the supported system to provide the TMDE test problem.

(3) Use 100% sampling plan when the number and/or characteristics of potential system faults are not too great for test item and cost considerations.

(4) When a 100% TMDE checkout is considered too time consuming or costly, design a sequential sampling plan. (A proposed sampling plan and a hypothetical example are shown in Appendix B.)

(5) Satisfy the following conditions when using a sequential sampling plan:

(a) Select test faults that are a random sample of the total population of potential faults.

(b) Insert the random sample of test faults in a random order.

(6) Consider the following precautions before inserting faults:

(a) Do not insert potential system faults that would damage the TMDE.

(b) Do not insert potential system faults that would damage the system.

b. Data required.

(1) Sampling plan used, 100% or sequential.

(2) If sequential, faults inserted in test TMDE and order in which inserted.

(3) Faults detected and isolated and/or faults not detected and isolated.

(4) List faults that damaged TMDE and the causes of damage (if known).

NOTE: Certain potential faults of particular interest which are not inserted during the sequential sampling test should be scheduled for testing during a special supplemental test. The identification of the total population of potential faults is accomplished by itemizing each individual piece or part (i.e., resistor, capacitor, transistor, etc.) and the various related failure modes (i.e., shorts, opens, grounds, biased values, etc.). If this task is considered too time consuming and costly, an alternate approach is to designate potential faults in each of the subassemblies or at some other convenient level until the sample is adequate for the sequential sampling plan being used.

4.6 Standard Design Characteristics. This test determines whether the TMDE is designed and configured in accordance with standard Army requirements.

a. Method.

(1) Check the TMDE characteristics against the criteria in the checklist (Fig. 2 of App C in AMCP 706-134[5]), and note any discrepancies.

(2) Add other checklists of AMCP 706-134 if considered appropriate.

b. Data required. List criteria met and/or not met.

4.7 TMDE Interface Tests. Conduct tests to determine any engineering-type discrepancies between the TMDE and the other elements of integrated logistic support. Review the TMDE in the following areas:

a. Method.

(1) Determine if common or other equipment in Army inventory could be adapted to satisfy the user's requirement in lieu of the system-peculiar TMDE under test.

(2) Determine if the system-peculiar TMDE is technically compatible with the common TMDE planned for the system.

(3) Determine if the technical manuals are technically adequate for using the system-peculiar TMDE.

(4) Determine if the planned calibration facilities are technically adequate to calibrate the system-peculiar TMDE in all areas.

b. Data required.

(1) Acceptable common or other equipment, and list advantages.

(2) Compatibility or incompatibility of system-peculiar TMDE with common TMDE planned for the system.

(3) Inadequacies of TMDE technical manuals.

(4) Inadequacies of calibration facilities in all areas of the system-peculiar TMDE.

4.8 Extreme Environments. Extreme-environment tests are conducted to determine whether the performance of the system-peculiar TMDE is degraded by exposure to the various extreme environmental conditions expected in field use. The following two factors are of particular concern in planning these tests: (1) each environmental exposure must be appropriate to the particular TMDE; (2) the scope of checks to detect TMDE physical and operational degradation must be adequate.

a. Method. As required, conduct tests in the following environmental conditions:

(1) Road and cross-country vibration. (See TOP's 2-2-808,[6] 1-2-601.[7])

(2) Laboratory shock and vibration. (See MIL-STD-810D,[8] TOP 1-2-601.)

(3) Rail transportation. (See MIL-STD-810D, TOP 1-2-500.[9])

(4) Radio frequency interference. (See TOP 6-2-542.[10])

(5) Rain. (See MIL-STD-810D, TOP 2-2-815.[11])

(6) Immersion in water. (See MIL-STD-810D, TOP 2-2-612.[12])

(7) Solar radiation. (See MIL-STD-810D, ITOP 4-2-826.[13])

(8) Sand and dust. (See MIL-STD-810D.)

(9) Humidity. (See MIL-STD-810D, TOP 4-2-820.[14])

(10) Salt fog. (See MIL-STD-810D.)

(11) Fungus. (See MIL-STD-810D.)

(12) Transit drop. (See MIL-STD-810D.)

(13) Logistics over the shore (LOTS).

(14) Air transport.

(15) Human factors evaluation. (See TOP 1-2-610.[15])

b. Data required.

(1) Test parameters for all environmental conditions.

(2) Reasons for failures in environments in which tested.

NOTE: The environmental conditions planned for the TMDE often differ significantly from those expected for the end item; often being less severe but never more severe. The environments for organizational, DS, and unit and intermediate levels of TMDE also often differ significantly from each other. The test planner must, therefore, review the requirements documents (ILSP/TPSMP), and other documents to clearly identify the field conditions appropriate to the TMDE. Once the field conditions are identified, the development of the test exposure conditions (i.e., miles, temperatures, etc.) should be accomplished using standard planning practices identified in TOP's, military standards, etc., of paragraph 4. The scope of physical and operational TMDE tests planned to be conducted before, during, and after each exposure is often abbreviated from the performance tests of paragraph 4 because of time and cost factors. In this respect there are at least two factors that should be taken into consideration when establishing the scope of the TMDE checks. The scope of TMDE checks should at least equal the scope of checks for systems of equal complexity. The scope of TMDE checks should reflect (1) the importance of TMDE performance in checking major performance parameters of the supported system and (2) the characteristics of the particular environment.

4.9 <u>High and Low Temperatures</u>. Both the high- and low-temperature tests have a storage phase and an operational phase. (See MIL-STD-810D and AR 70-38.[16])

a. Method.

(1) Unless specifically designated otherwise, conduct the <u>high-temperature storage and operational tests</u> and the <u>low-temperature storage tests</u> of TMDE at the same temperatures and for the same durations as those of the end item.

(2) The low-temperature operational test for TMDE may be more moderate than that of the end item and will be in accordance with the requirements documents (AP, ILSP/TPSMP).

b. Data required.

(1) Parameters for high- and low-temperature tests.

(2) If known, the causes of operational failures during temperature tests (high and low).

4.10 Logistic Supportability Evaluation.

a. Method. Conduct this test to determine whether the system-peculiar TMDE can meet specified maintenance requirements. Ensure that this evaluation addresses the maintenance characteristics of the TMDE and the adequacy of its system support package elements as compared to the end item characteristics.

b. Data required. Note any faults, discrepancies, or failures encountered.

5. DATA PRESENTATION.

a. Prepare a block diagram of the test setup employed in each test. The block diagram shall identify by model and serial number, all test equipment and interconnections (cable lengths, connectors, attenuators, etc.), and indicate control and dial settings where necessary.

b. Take photographs and/or motion pictures, and prepare sketches, charts, graphs, video tapes, and/or other pictorial or graphic materials to support test results or conclusions.

c. Keep an engineering logbook containing, in chronological order, pertinent remarks and observations to aid in analysis of test data.

d. Test criteria and/or test-item specifications shall be noted with test data presentation to aid comparison and analysis.

Recommended changes to this publication should be forwarded to Commander, US Army Test and Evaluation Command, ATTN: AMSTE-AD-M, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity, Commander, US Army Combat Systems Test Activity, ATTN: STECS-AD-A, Aberdeen Proving Ground, MD 21005-5059. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22304-6145. This document is identified by the accession number (AD No.) printed on the first page.

APPENDIX A

BACKGROUND

US Army field-type systems are designed and issued with a wide variety of TMDE. This equipment is used to perform status evaluations, troubleshooting and repair actions, and requalification maintenance functions on the supported end items. Of the several basic categories of this equipment (i.e., common, special, and system-peculiar), the system-peculiar TMDE (hardware, software, documentation) is the sole concern in this TOP.

System-peculiar TMDE is equipment designed to support only one end item of Army materiel. There are two types: built-in test/built-in test equipment (BIT/BITE) and separate test equipment. This equipment may be designed for use at one or more of the maintenance levels--unit, intermediate (direct support and general support), and depot--depending on the particular situation. For example, BITE is commonly used by the end item operator, and its maintenance may be performed by a combination of efforts at the unit and one or more of the other maintenance levels or at the unit and depot levels only.

BIT/BITE is normally tested concurrently with the DT II and DT III of the end item to which it is mounted. Separate TMDE is preferably tested concurrently with the test item, but if it is developed out of phase with the test item, testing may occur at a later time.

In test planning, the system-peculiar TMDE to be tested is considered to be one of the many elements of the logistic support planned for a particular end item. Test planners must, therefore, consider not only the interface between the TMDE and the end item but also the TMDE interface with the other elements of the planned logistic support such as the manuals, common test equipment and tools, repair parts, calibration facilities, etc.

Criteria for the test plan include not only the requirements stated in the requirements documents (AP) and test directive but also applicable statements in the TPSMP and ILSP. The IEP/TDP must be provided in sufficient organization and detail to provide a systematic and comprehensive means for evaluating the equipment relative to each test criterion and issue.

Proper testing of TMDE cannot be achieved (as has sometimes occurred in the past) if the TMDE is put to use only when there is a problem during the testing of the end item. To test the TMDE, certain faults must be planted in the end item to determine whether proper diagnosis can be achieved. Additionally, if the TMDE is to be taken into the field with its end item, it must be subjected to the same environmental conditions as the end item.

APPENDIX B

PROPOSED SAMPLING PLAN FOR DETERMINING ABILITY OF SYSTEM-PECULIAR TMDE TO DETECT POTENTIAL FAULTS

Component faults are intentionally programmed into a system and observations are made whether the TMDE can detect those faults. The sampling plan below is based on a sequential probability ratio test when the underlying parameter is binomial. (For further information see Chap. 5 of ref 17.) This sampling concept may be adapted for use in other TMDE performance tests of paragraph 4 of this TOP.

A system that is to be diagnosed and, perhaps, maintained will have component faults or failures occurring during testing. The types of faults can be many and the numbers extremely large. This sampling plan is designed for accepting or rejecting the TMDE. The sampling plan is based on the assumption that the probability of <u>not</u> detecting a fault (p) is constant from trial to trial no matter which fault occurs. Faults should be selected by some random process.

To construct a test of hypothesis, two values of p must be selected. Let the fraction implying good TMDE equipment be denoted by p_0, and let the fraction implying bad TMDE be denoted by p_1 ($p_1 > p_0$). If the true p is p_0 or smaller, the risk of rejecting the hypothesis ($p = p_0$) is α or less (type I error); if the true p is p_1 or larger, the risk of accepting the hypothesis is β or less (type II error).

A sampling plan satisfying the conditions that the probability of rejecting proper detection of faults does not exceed α whenever $p \leq p_0$, and the probability of accepting proper detection of faults does not exceed β whenever $p \geq p_1$, is given by the sequential probability ratio test of strength (α, β) for testing the hypothesis $p = p_0$ against the hypothesis $p = p_1$. To carry out the test, the acceptance number a_k and the rejection number r_k are calculated. (They depend only on p_0, p_1, α, β, k and can be calculated prior to actual testing.) The process of fault injection is continued as long as $a_k < x_k < r_k$ where x_k denotes the number of failures (failure to properly detect a fault) in the k trials. The first time that x_k does not lie in the interval (a_k, r_k), the fault injection is terminated. If $x_k \geq r_k$, the hypothesis is rejected; if $x_k \leq a_k$, it is accepted. The acceptance number and the rejection number are given below.

$$a_k = \frac{\ln\left(\frac{\beta}{1-\alpha}\right)}{\ln\left(\frac{p_1}{p_0}\right) - \ln\left(\frac{1-p_1}{1-p_0}\right)} + k\,\frac{\ln\left(\frac{1-p_0}{1-p_1}\right)}{\ln\left(\frac{p_1}{p_0}\right) - \ln\left(\frac{1-p_1}{1-p_0}\right)}$$

$$r_k = \frac{\ln\left(\frac{1-\beta}{\alpha}\right)}{\ln\left(\frac{p_1}{p_0}\right) - \ln\left(\frac{1-p_1}{1-p_0}\right)} + k\,\frac{\ln\left(\frac{1-p_0}{1-p_1}\right)}{\ln\left(\frac{p_1}{p_0}\right) - \ln\left(\frac{1-p_1}{1-p_0}\right)}$$

k = 1, 2,..., until decision is reached or until truncation.

These can be calculated before the test and prepared in tabular or graphical form for quick reference during the test.

The sequential sampling plan does not provide any definite upper limit for the number of faults, N, to be programmed. Any large value of N is possible, but the probability is small that N will exceed twice or three times its expected value.

It is sometimes desirable to set a definite high upper limit N_0 for N. This can be done by truncating the sequential process at $N = N_0$ where N_0 is approximately three times the maximum expected value of N. Although the truncation process alters the risks, this effect is negligible for practical purposes when N_0 is chosen as described above. The following is a reasonable rule for deciding acceptance or rejection at $N = N_0$ if no decision is reached for $N \le N_0$ with the regular sequential procedure:

If $x_{N_0} < 1/2(a_{N_0} + r_{N_0})$, accept;

If $x_{N_0} \ge 1/2(a_{N_0} + r_{N_0})$, reject.

Additionally, if x_{N_0} failures occur prior to N_0, reject immediately.

The expected value of N depends on the fraction of programmed component failures that fail to be detected. The maximum expected value of N usually occurs at approximately

$$E(N) = \frac{\ln\left(\frac{\beta}{1-\alpha}\right) \cdot \ln\left(\frac{1-\beta}{\alpha}\right)}{\ln\left(\frac{p_1}{p_0}\right) \cdot \ln\left(\frac{1-p_1}{1-p_0}\right)}, \text{ thus } N_0 = 3\,E(N)$$

Example:

Suppose the hypothesis p = .10 against the hypothesis p = .15 is to be tested. Further suppose the risk and risk are taken as 0.10 and 0.20, respectively. The truncation number can be determined as follows:

$$N_0 = 3 \cdot \frac{\ln\left(\frac{\beta}{1-\alpha}\right) \cdot \ln\left(\frac{1-\beta}{\alpha}\right)}{\ln\left(\frac{p_1}{p_0}\right) \cdot \ln\left(\frac{1-p_0}{1-p_1}\right)}$$

$$= 3 \times \frac{\ln(2/9)\ \ln(8)}{\ln(1.5)\ \ln(0.85/0.90)} = 3\ (135) = 405$$

The acceptance and rejection numbers are calculated from the linear relations:

$$a_k = -3.251 + 0.124\ k$$

$$r_k = 4.495 + 0.124\ k$$

This plan is represented graphically in Figure B-1.

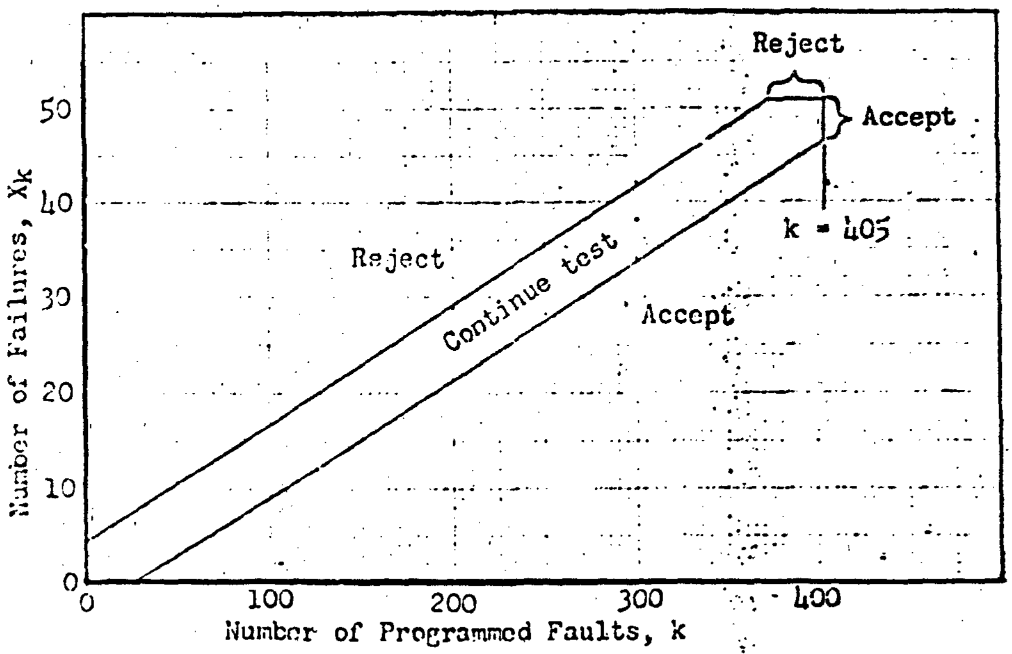

Figure B-1. Sample plot of acceptance-rejection criteria.

APPENDIX C

TEST EQUIPMENT (TMDE) CHECKLIST
(From AMCP 706-134)

1. Are the instructions for using test equipment in step-by-step format?
2. Is a signal provided which shows when the test equipment is warmed up?
3. If it is not feasible to present such a signal, is the warm-up time required clearly indicated near the warm-up switch?
4. Is a simple check provided to indicat when the test equipment is out of calibration or is otherwise not functioning?
5. Is appropriate indication of test equipment performance provided so the technician does not attempt to measure with a faulty standard or instrument out of calibration?
6. Do test equipment displays which require transformation of values have conversion tables attached to the equipment with the transform factor by each individual switch position or display scale?
7. Is adequate support provided for test equipment which must be taken into the work area so the technician does not have to hold the test equipment or take separate support devices to the work area for this purpose?
8. Are built-in test features provided wherever standard portable test equipment cannot be used?
9. Does portable test equipment packaging reflect the manner in which the equipment will be carried (i.e., size, shape, e.g., location of hand grips, clearance of technician's leg and of the floor, etc.)?
10. Does portable test equipment weigh under 14 lb if it is to be carried by one man?
11. Do plugs, jacks, and binding posts used for testing test equipment appear on outer casing of equipment so it is not necessary to remove the case? If internal repair requires removal of case, are duplicate jacks, plugs, etc. provided on chassis so jury-rig connections to the case are not necessary?
12. Are display lights, automatic power switches, or printed warnings provided to ensure that test equipment is turned off when testing is completed?
13. Is storage for cable and test leads (within test instrument case or lid) designed so loose cable cannot interfere with closure of case?
14. Is purpose of test equipment and special cautions displayed in a conspicuous place on the outer surface of the test equipment?
15. Are units which are not self checking designed to be checked in the operating condition without the aid of special rigs and harnesses wherever possible?
16. Are selector switches provided in lieu of a number of plug-in connectors?
17. Is test equipment designed to be capable of connection to prime equipment within two minutes?

APPENDIX D
REFERENCES

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