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Materiel Test Procedure 6-3-330  
U. S. Army Artillery Board

U. S. ARMY TEST AND EVALUATION COMMAND  
COMMODITY SERVICE TEST PROCEDURE

3455

DIRECTION FINDING EQUIPMENT, GYROSCOPE

1. OBJECTIVE

The purpose of this MTP is to describe the methods, techniques, and test requirements necessary for the determination of the degree to which gyroscopic direction finding equipment can perform the mission prescribed for it in the applicable Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC) and its suitability for use by the Army.

2. BACKGROUND

The general requirement for improved all-weather equipment for extending survey control in support of artillery operations has led to rapid advances in the development of improved distance measuring equipment. To keep pace with this advanced capability, the development of new methods for obtaining accurate azimuths, day or night, in all weather conditions, has become necessary. Such equipment can provide artillery units with a rapid, reliable means for establishing directional control in tactical situations, thereby expediting survey operations.

Gyroscopic direction finding equipment has been in use by the artillery for survey operations for a number of years. However, a continuing effort to develop improved, lightweight instruments reflects the need for updating and perfecting equipment of this type. As this equipment becomes ready for use, a testing program for ensuring that performance standards are met must also be developed.

3. REQUIRED EQUIPMENT

- a. Suitable Test Sites and Facilities, for conducting the applicable subtests.
- b. Surveyed Test Positions with known Azimuths to Various Stations.
- c. Maintenance Support Facilities.
- d. Communications Equipment and Facilities, as required.
- e. Equipment and Facilities, as required by the referenced MTP's.
- f. Equipment, as required by reference 4G.
- g. Vehicles for Transporting of Test Equipment and Personnel, as required.
- h. Acoustic Aids.
- i. Electronic Ranging Instruments, as required.
- j. Optical Instruments.
- k. Camouflage Materials, as required.
- l. Shelter Materials, as required.
- m. Aerial Cameras with Film.
- n. Aerial Photo Interpretation Facilities.
- o. Repair Parts.
- p. Batteries.

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q. Battery Charging Facility.

4. REFERENCES

- A. QMR for the test item.
- B. USATECOM Regulation 385-6, Safety Release.
- C. USATECOM Regulation 385-7, Safety Confirmation.
- D. USATECOM Regulation 385-13, Safety Statements for Materiel in Development.
- E. USATECOM Regulation 750-15, Maintenance of Supplies and Equipment - Maintenance Portion of the Service Test.
- F. AR 705-15, Operation of Materiel Under Extreme Conditions of Environment.
- G. D.A. FM 6-2, Artillery Survey, August 1965.
- H. MTP 6-3-500, Physical Characteristics.
- I. MTP 6-3-501, Technical Inspection.
- J. MTP 6-3-502, Personnel Training Requirements.
- K. MTP 6-3-505, Emplacement, Preparation for Action and March Order.
- L. MTP 6-3-506, Durability.
- M. MTP 6-3-509, Effects of Weather.
- N. MTP 6-3-510, Transportability of Communication, Surveillance and Electronic Equipment.
- O. MTP 6-3-512, Compatibility with Related Equipment.
- P. MTP 6-3-513, Qualitative Electronic Interference.
- Q. MTP 6-3-514, Qualitative Frequency Accuracy and Stability.
- R. MTP 6-3-517, Electrical Power Requirements.
- S. MTP 6-3-523, Safety.
- T. MTP 6-3-524, Maintenance Evaluation.
- U. MTP 6-3-525, Human Factors.
- V. MTP 7-3-512, Air Drop Capability (Suitability of Equipment for).
- W. MTP 7-3-515, Air Transport, Internal (Suitability of Equipment for).

5. SCOPE

5.1 SUMMARY

This MTP describes the methodology, techniques and the subtests required for the determination of the man-equipment compatibility and the capability and suitability of the test item as a direction-finding instrument. The major areas and their included subtests are:

a. Pre-Test Operations consisting of:

- 1) Technical Inspection - A check to verify that the test item is complete and in satisfactory condition prior to the start of testing.
- 2) Physical Characteristics - A verification of the physical characteristics of the test item.
- 3) Electrical Characteristics - A verification of the test item's electrical characteristics and a determination of its power requirements, including battery life.

b. Operational Characteristics consisting of:

- 1) Emplacement, Preparation for Action and March Order Suitability - A determination of the ability of service personnel to set up the test item for operation under various conditions and to restore it to its transport configuration.
- 2) Accuracy and Precision of Measurement - A determination of the degree of accuracy of measurement that the test item can attain.
- 3) Frequency Accuracy and Stability - A determination of the test item capability to maintain accurate operating frequencies under tactical conditions.

c. Transportability Tests consisting of:

- 1) Surface Transportability - A determination of the suitability of the test item for surface transport.
- 2) Air Transportability - A determination of the suitability of the test item for internal transport by aircraft.

d. Vulnerability to Detection - A determination of the degrees of security from aural and visual detection that the test item offers in its various configurations. Ground and aerial observations are included.

e. Compatibility with Related Equipment - A determination of the suitability of the test item for operations with its related equipment, in various configurations.

f. Communications and Electronic Equipment Interference Effects - A determination of the degree and security of interference from communications and electronic equipment operating in proximity to the test item, including magnetic field interference.

g. Full-Test Evaluations consisting of:

- 1) Durability - An evaluation of the capability of the test item to withstand being transported over various types of terrain for a specified number of miles.
- 2) Maintainability and Reliability - An evaluation to determine the suitability of the test item to be maintained, the adequacy of its maintenance package, and its overall ability to operate over long periods of time without adjustment or replacement of components.
- 3) Effects of Weather - An evaluation of the effects of various weather conditions on the operability of the test item.
- 4) Human Factors - An evaluation of the suitability of the test item for operation, servicing, transport and storage by service personnel without causing undue fatigue and mental errors.
- 5) Safety - An evaluation of the safeness of the test item in its various configurations, under a variety of conditions, and resultant safety hazards to service personnel.
- 6) Value Analysis - Observations of the test item during the period of testing to determine possible ways to eliminate unnecessary costs at various stages of the design development and testing program.

h. Post-Test Inspection - A repetition of the technical inspection to determine any adverse effects of testing on the test item.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Scheduling

6.1.1.1 Personnel

a. Ensure the availability of service personnel who have been trained according to the criteria of MTP 6-3-502 and are knowledgeable about the following aspects of the test item:

- 1) Installation
- 2) Operation
- 3) Maintenance

b. Record the following for all service test personnel:

- 1) Rank
- 2) MOS
- 3) Training time in MOS
- 4) Experience in MOS

NOTE: Test personnel shall receive the minimum essential individual instruction in the operation and organizational, direct support maintenance of the test item. The achievement of a skill level to operate the test item under simulated tactical conditions shall be a requirement, assuming that the test item can achieve results as set forth in the applicable QMR. Observations of operations and maintenance activities shall be made by technically qualified personnel.

c. Ensure that experienced personnel are available for the duration of testing.

6.1.1.2 Facilities and Equipment.

a. Select and schedule the use of testing sites and facilities as required by the applicable subtests.

NOTE: For best results, the test item should be protected from the weather by a shelter. Wind gusts may be sensed by the gyro and result in erratic operation. (Tree roots carry the effects of wind gusts into the ground) Direct sun rays may cause erratic operation due to unequal expansion and contraction of the various parts of the unit.

b. Upon notice of the arrival or estimated time of arrival of the test

item, arrange for or secure the following:

- 1) Engineering safety release or a safety statement from the engineering agency as prescribed by references 4B and 4D
- 2) Vehicles for transporting the test items, as applicable.
- 3) Maintenance support facilities, organization and personnel.
- 4) Assistance of the U. S. Army Airborne, Electronics and Special Warfare Board (USAAESWBD), as required, during the conduct of aerial delivery and air drop operations.
- 5) Verify that surveyed positions, as required, at the testing sites, are available.

#### 6.1.2 Safety

- a. Verify that the test item safety documents are valid and up-to-date.
- b. Verify that all service test personnel have been adequately trained in the safety requirements pertaining to the test item and the testing.

#### 6.1.3 Pre-Test Operations

##### 6.1.3.1 Technical Inspection

Conduct a technical inspection of the test item as described by the applicable sections of MTP 6-3-501.

##### 6.1.3.2 Physical Characteristics

Determine the physical characteristics of the test item as described by the applicable sections of MTP 6-3-500.

##### 6.1.3.3 Electrical Characteristics

Determine the electrical characteristics and the power requirements of the test item as described by the applicable sections of MTP 6-3-517.

#### 6.2 TEST CONDUCT

- a. Subtests shall be conducted concurrently with, or in conjunction with, other subtests, whenever possible, so that the time taken to collect the required data can be minimized.
- b. Subtests shall be conducted under the conditions of weather prevailing during the period of testing.

#### 6.2.1 Operational Characteristics

At the completion of each subtest for the evaluation of operational characteristics or as specified, the test item shall be subjected to a technical inspection as described by the applicable sections of MTP 6-3-501.

##### 6.2.1.1 Daylight Conditions

Perform paragraphs 6.2.1.1.1 through paragraph 6.2.1.1.3 under day-light conditions.

6.2.1.1.1 Emplacement, Preparation for Action and March Order Suitability - Determine the suitability of the test item for being emplaced, prepared for action, and march ordered according to the criteria of MTP 6-3-505.

NOTE: This subtest shall be performed in conjunction with other subtests, as applicable.

6.2.1.1.2 Accuracy and Precision of Measurement - Perform the following using a test item unprotected by any kind of shelter and powered by a d.c. power source:

a. Locate the test item on a line whose azimuth is known to an accuracy which is at least one order greater than the test item's required capability.

- NOTE:
1. When possible, line azimuth accuracy should be second order or better.
  2. Prior to commencing observations, subject the test item to the technical inspection of paragraph 6.2.1.

b. Obtain a set of 10 readings for the azimuth line direction on the test item and record the following for each reading:

- 1) Ambient temperature
- 2) Azimuth bearing of line

c. Transport the test item to a second position located on a line whose azimuth is known to an accuracy at least one order greater than the test item's required capability and repeat step b.

NOTE: The line azimuth in relation to the required test item readout shall be in a different quadrant from that of line of step a.

d. Repeat step c two more times with the line azimuths located in each of the quadrants not covered in steps a and c.

e. Repeat steps a through d with the test item having the following degrees of shelter:

- 1) Sheltered only from the sun
- 2) Sheltered from the sun and wind
- 3) Sheltered as completely as possible from all elements

f. Repeat steps a through e a minimum of three times.

g. Repeat steps a through f using an a.c. power source, if applicable.

6.2.1.1.3 Frequency Accuracy and Stability - Determine the qualitative frequency, accuracy and stability of the test item as described by the applicable sections of MTP 6-3-514.

6.2.1.2 Darkness Conditions

Repeat paragraphs 6.2.1.1.1 through 6.2.1.1.3 under conditions of darkness, as applicable.

6.2.2 Transportability Tests

6.2.2.1 Surface Transportability

a. Determine the surface transportability of the test item as described by the applicable sections of MTP 6-3-510.

b. At the completion of the testing, subject the test item to a technical inspection as described by the applicable sections of MTP 6-3-501.

c. Verify the operability of the test item by subjecting it to an accuracy and precision test as described in paragraph 6.2.1.1.2, steps a and b.

6.2.2.2 Air Transportability

NOTE: The conduct of air transportability testing shall be coordinated with the U. S. Army Airborne, Electronics and Special Warfare Board (USAAESWBD), if required.

a. Determine the suitability of the test item for air drop as prescribed by the applicable sections of MTP 7-3-512.

b. Determine the suitability of the test item for internal air transport as described by the applicable sections of MTP 7-3-515.

c. At the completion of testing, subject the test item to a technical inspection as described by the applicable sections of MTP 6-3-501.

d. Verify the operability of the test item by subjecting it to an accuracy and precision test as described in paragraph 6.2.1.1.2, steps a and b.

6.2.3 Vulnerability to Detection

Observations of the test item shall be made during operational testing.

6.2.3.1 Daylight Conditions

a. Determine and record the maximum distance at which the test item and its associated power equipment are audible to:

- 1) Unaided ear
- 2) Acoustic aids

b. Determine and record the maximum distance at which the test item is discernible without camouflage and with camouflage from ground positions using:

- 1) Unaided vision
- 2) Optical instruments
- 3) Electronic instruments, when applicable

c. Determine and record the maximum altitudes at which the test item

is discernible without camouflage and with camouflage from aerial observations using:

- 1) Unaided vision
- 2) Optical instruments
- 3) Aerial photography

NOTE: The conduct of airborne operations shall be coordinated with the U. S. Army Airborne, Electronics, and Special Warfare Board (USAAESWBD), if required.

#### 6.2.3.2 Darkness (Blackout) Conditions

Repeat paragraph 6.2.3.1 under conditions of darkness (blackout).

#### 6.2.4 Compatibility with Related Equipment

Determine the compatibility of the test item with related components and devices as described by the applicable sections of MTP 6-3-512.

#### 6.2.5 Communications and Electronic Equipment Interference Effects

Determine the effects of operating the test item in positions near wire and electronic communication devices and ranging devices (i.e., radar, sound ranging) and computers in accordance with the criteria of MTP 6-3-513.

#### 6.2.6 Full Test Evaluations

During the conduct of this MTP, the following test item characteristics shall be determined and/or evaluated.

##### 6.2.6.1 Durability

a. Determine the durability and ruggedness of the test item as described by the applicable sections of MTP 6-3-506.

NOTE: The test item shall be transported over paved roads, unpaved roads, and cross-country terrain for a minimum of 300 miles, in all transportable configurations.

b. Evaluate the ability of the test item field transit case(s) to protect the test item from shock and vibration.

##### 6.2.6.2 Maintainability and Reliability

NOTE: The overall evaluation of the maintainability and reliability of the test item shall be made according to the criteria of reference 4E.

a. Complete the authorized maintenance tasks in accordance with the test item maintenance instructions and technical literature.

b. Determine the maintainability of the test item as described by the applicable sections of MTP 6-3-524.

c. Record the following, as applicable:

- 1) Time and number of personnel required to perform scheduled and non-scheduled maintenance tasks on the test item.
- 2) Frequency of repairs.
- 3) Test item downtime (cumulative).
- 4) Nomenclature of repair parts used.
- 5) Maintenance responsibilities and capabilities at organizational, direct support and general support levels.

d. Evaluate the adequacy and accuracy of the test item maintenance package.

#### 6.2.6.3 Effects of Weather

a. Determine the effects of weather on the test item operability as described by the applicable sections of MTP 6-3-509.

b. Evaluate the ability of the test item field transit case(s) to protect the test item from moisture, dust and other debris.

#### 6.2.6.4 Human Factors

a. Determine the suitability of the test item design with respect to the man-equipment relationship as described by the applicable sections of MTP 6-3-525.

b. Determine and record the suitability and the compatibility of the test item with the service personnel who will operate and service it, with respect to their skills, aptitudes and physical limitations.

NOTE: Each test item detail requiring human attention and/or manipulation shall be observed and evaluated.

#### 6.2.6.5 Safety

a. Determine the test item safety hazards resulting from storage, transport, operation, and maintenance as described by the applicable sections of MTP 6-3-523.

b. Prepare a safety confirmation in accordance with USATECOM Regulation 385-7.

#### 6.2.6.6 Value Analysis

Record observations concerning possible ways to eliminate unnecessary costs during the design, development and procurement of the test item without compromise to the following:

- a. Quality of components
- b. Reliability (overall)
- c. Maintainability

- d. Operational performance
- e. Mission accomplishment

NOTE: Observations shall include, but shall not necessarily be limited to, non-essential or nice-to-have features, components or accessories.

#### 6.2.7 Post-Test Inspection

Upon completion of testing the test item shall be subjected to a technical inspection as described by the applicable sections of MTP 6-3-501 and any deleterious effects on the test item, due to the testing program, shall be recorded.

### 6.3 TEST DATA

#### 6.3.1 Preparation for Test

##### 6.3.1.1 Personnel

Record the following for all service personnel:

- a. Rank
- b. MOS
- c. Training time in MOS, in months
- d. Experience in MOS, in years

##### 6.3.1.2 Pre-Test Operations

###### 6.3.1.2.1 Technical Inspection -

Record data as collected under the applicable sections of MTP 6-3-501.

###### 6.3.1.2.2 Physical Characteristics -

Record data as collected under the applicable sections of MTP 6-3-500.

###### 6.3.1.2.3 Electrical Characteristics -

Record data as collected under the applicable sections of MTP 6-3-517.

#### 6.3.2 Test Conduct

##### 6.3.2.1 Operational Characteristics

Record the following for each subtest conducted:

- a. Visibility condition (daylight, darkness)
- b. Test item nomenclature
- c. Weather conditions (clear, rainy, etc.)

6.3.2.1.1 Emplacement, Preparation for Action, and March Order Suitability -

- a. Record data as collected under the applicable sections of MTP 6-3-505.
- b. Record technical inspection data, collected as described in the applicable sections of MTP 6-3-501.

6.3.2.1.2 Accuracy and Precision of Measurement -

- a. Record the following for each set of readings:
  - 1) Line azimuth to nearest 0.01 mil, in mils
  - 2) Protection afforded test item (none, sun only, etc.)
  - 3) Power supply source (AC, DC)
  - 4) Ambient temperature, in °F
  - 5) Set number (1, 2, 3)
  - 6) For each reading of each set:
    - a) Reading number (1, 3, 5, etc.)
    - b) Test instrument azimuth, in mils
  - 7) Test set mean average azimuth, in mils
  - 8) Test set standard deviation, in mils
- b. Record the technical inspection data collected as described in the applicable sections of MTP 6-3-501.

6.3.2.1.3 Frequency, Accuracy and Stability -

- a. Record data as collected under the applicable sections of MTP 6-3-514.
- b. Record technical inspection data, collected as described in the applicable sections of MTP 6-3-501.

6.3.2.2 Transportability Tests

6.3.2.2.1 Surface Transportability -

- a. Record data as collected under the applicable sections of MTP 6-3-510.
- b. Record technical inspection data, collected as described in the applicable sections of MTP 6-3-501.
- c. Record data, collected as described in step b of paragraph 6.2.1.1.2.

6.3.2.2.2 Air Transportability -

- a. Record data as collected under the applicable sections of MTP 7-3-512 and MTP 7-3-515.
- b. Record technical inspection data, collected as described in the applicable sections of MTP 6-3-501.
- c. Record data, collected as described in step b of paragraph 6.2.1.1.2.

6.3.2.3 Vulnerability to Detection -

a. Record the following for each aural observation:

- 1) Visibility condition (daylight, darkness).
- 2) Maximum distances, in meters, at which the test item and associated equipment can be detected by:
  - a) Unaided ear
  - b) Acoustic aids
- 3) Test item operational condition (operational, standby).

b. Record the following for each visual observation from ground positions:

- 1) Visibility condition (daylight, darkness).
- 2) Test item emplacement condition (camouflaged, uncamouflaged).
- 3) Maximum distances, in meters, at which the test item is discernible by:
  - a) Unaided vision
  - b) Optical instruments
  - c) Electronic instruments, when applicable

c. Record the following for each visual observation from aircraft:

- 1) Visibility condition (daylight, darkness).
- 2) Test item emplacement condition (camouflaged, uncamouflaged).
- 3) Maximum altitudes, in feet or meters, at which the test item can be detected by:
  - a) Unaided vision
  - b) Optical instruments
  - c) Aerial photography

6.3.2.4 Compatibility with Related Equipment

a. Record data as collected under the applicable sections of MTP 6-3-512.

b. Record technical inspection, collected as described in the applicable sections of MTP 6-3-501.

6.3.2.5 Communications and Electronic Equipment Interference Effects

Record data as collected under the applicable sections of MTP 6-3-513.

6.3.2.6 Full-Test Evaluations

6.3.2.6.1 Durability -

Record data as collected under the applicable sections of MTP 6-3-506.

6.3.2.6.2 Maintainability and Reliability -

Record the following:

- a. Data as collected under the applicable sections of MTP 6-3-524.
- b. Type of maintenance performed (scheduled, non-scheduled).
- c. Time required to perform each maintenance task, in hours and minutes.
- d. Number of personnel required to perform each maintenance task.
- e. Frequency of repairs over the period of testing (record dates).
- f. Test item downtime (cumulative), in hours and minutes.
- g. Nomenclature of repair parts used.
- h. Maintenance responsibilities and capabilities at organizational, direct support and general support levels.

6.3.2.6.3 Effects of Weather -

Record data as collected under the applicable sections of MTP 6-3-509.

6.3.2.6.4 Human Factors -

Record the following:

- a. Data as collected under the applicable sections of MTP 6-3-525.
- b. Observations of service personnel during testing, and the suitability of the test item with respect to their:

- 1) Skills
- 2) Aptitudes
- 3) Physical limitations

6.3.2.6.5 Safety -

Record data as collected under the applicable sections of MTP 6-3-523.

6.3.2.6.6 Value Analysis -

Record observations concerning possible ways to eliminate unnecessary costs during the design, development and procurement of the test item without compromise to the following:

- a. Quality of components
- b. Reliability (overall)
- c. Maintainability
- d. Operational performance
- e. Mission accomplishment

6.3.2.7 Post-Test Inspection

- a. Record data as collected under the applicable sections of MTP 6-3-501.

b. Record any deleterious effects of the test program on the test item.

#### 6.4 DATA REDUCTION AND PRESENTATION

Data obtained from all subtests covered by applicable MTP's shall be summarized and evaluated according to procedures described in those applicable MTP's. Appropriate charts, graphs, and tabulated summaries shall be used to present the data in a clear manner. Special consideration shall be given to any condition or circumstance contributing to any test result.

Calculations shall be performed as specified by the individual MTP's and references, wherever applicable, and all photographs, motion pictures and illustrative material shall be suitably identified.

The evaluation of the test item measurement accuracy shall be based on the summarized data and on the comparison with the actual line azimuth and analyzed using the technique described in Appendix A (chi-squared goodness of fit).

The qualitative and quantitative data collected shall also be evaluated in terms of the requirements specified in the QMR's and TC's, which are applicable, to determine the degree of fulfillment of the test item performance specifications.

For the evaluation of the vulnerability of the test item to detection, average distances and altitudes shall be computed, tabulated and compared for the various observation methods under the various conditions.

Coordination with the engineering test activity is essential to establish common parameters for computation of a standard deviation or sigma error. Without such coordination, one or both commodity tests may lack validity. Using the same parameters, it is probable that an order of accuracy achieved under controlled conditions (engineering test) will not be attainable in a service test environment, involving man-machine interface.

A safety confirmation based on the data of paragraph 6.3.2.6.5, shall be presented in accordance with USATECOM Regulation 385-7.

APPENDIX A

CHI-SQUARED GOODNESS FIT TEST

1. INTRODUCTION

The chi-squared ( $\chi^2$ ) goodness and fit test may be used to test the validity of any assumed distribution, either discrete or continuous.

The test may be summarized for a continuous distribution as follows:

- a. Determine the underlying distribution to be tested.
- b. Determine a level of significance,  $\alpha$ , which is defined as the risk of rejecting the underlying distribution if it is, in fact, the real distribution.
- c. Divide the continuous scale into intervals. For reliability analysis this scale is usually time.
- d. Determine the number of sample observations falling within each interval.
- e. Using the assumed underlying distribution, determine the expected number of observations in each interval. Combining of intervals may be required because the expected number of observations in an interval must be at least 2.5. This determination may require an estimation of the distribution parameters from sample data.

f. Compute

$$\chi^2 = \sum_{i=1}^k \frac{(O_i - E_i)^2}{E_i}$$

where

$O_i$  = number of sample observations in the  $i^{\text{th}}$  interval

$E_i$  = expected number of observations in the  $i^{\text{th}}$  interval

$k$  = number of intervals

NOTE: if  $\chi^2 = \sum_i^k \frac{(O_i - E_i)^2}{E_i} > \chi^2_{\alpha, k-p-1}$  reject the distribution

under test, otherwise, we do not have sufficient evidence to reject the assumed underlying distribution.

where  $p$  is the number of parameters estimated and  $\chi^2_{\alpha, k-p-1}$  can be found in Table A-III.

The  $\chi^2$  test may also be used for testing the validity of an assumed discrete distribution. The method is the same as for the continuous distribution except that each interval is comprised of a specific value or values of the discrete random variable.

2. EXAMPLE

a. Problem: To illustrate the use of the  $\chi^2$  goodness of fit test for a continuous distribution, consider the data in Table A-I indicating the failure times obtained from testing a sample of 100 items. Using a significance level of .05, test whether the assumption of an exponential distribution is reasonable. The sample mean was found to be 8.9 hours.

TABLE A-I  
OBSERVED DATA

Interval Hours	Frequency
0 - 5.05	48
5.05 - 10.05	22
10.05 - 15.05	11
15.05 - 20.05	7
20.05 - 25.05	3
25.05 - 30.05	5
30.05 - 35.05	2
35.05 - 40.05	0
40.05 - 45.05	1
45.05 - 50.05	0
50.05 - 55.05	1
	100

b. Solution: Table A-II is used as a means of computing

$$\sum_{i=1}^k \frac{(O_i - E_i)^2}{E_i}$$

TABLE A-II  
EXPECTED DATA

Interval (hrs) ( $L_i - U_i$ )	Observed Frequency	Frequency	$O_i - E_i$	$(O_i - E_i)^2$	$\frac{(O_i - E_i)^2}{E_i}$
0 - 5.05	48	43	5	25	.58
5.05 - 10.05	22	25	-3	9	.36
10.05 - 15.05	11	14	-3	9	.64
15.05 - 20.05	7	7	0	0	0
20.05 - 25.05	3	5	-2	4	.80
25.05 - 30.05	5	3	2	4	1.33
30.05 - 35.05	2	3	1	1	.33
35.05 - 40.05	0				
40.05 - 45.05	1				
45.05 - 50.05	0				
50.05 -	1				
					4.04

The expected frequency ( $E_i$ ) is found by multiplying the sample size by the probability of falling within the  $i^{\text{th}}$  interval if the assumed distribution is true.

$$E_i = n \left[ \exp\left(\frac{-L_i}{\theta}\right) - \exp\left(\frac{-U_i}{\theta}\right) \right] = 100 \left[ \exp\left(\frac{-L_i}{8.9}\right) - \exp\left(\frac{-U_i}{8.9}\right) \right]$$

where  $U_i$  and  $L_i$  are the upper and lower limits of the  $i^{\text{th}}$  interval,  $U_i = L_i + 1$ , and  $\theta = 8.9$  hours.

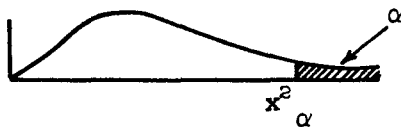
Some of the original intervals were combined to satisfy the requirement that no  $E_i$  value be less than 2.5.

$$\chi^2 = \sum_{i=1}^7 \frac{(O_i - E_i)^2}{E_i} = 4.04$$

$\chi^2 \alpha, k-p-1 = \chi^2 .05, 7-1-1 = \chi^2 .05, 5 = 11.070$  (Table A-III).

Since  $\sum_{i=1}^7 \frac{(O_i - E_i)^2}{E_i} = 4.04 < \chi^2 .05, 5 = 11.070$ , we do not have sufficient evidence to reject the exponential distribution as a model for these failure times.

TABLE A-III  
 $\chi^2$  DISTRIBUTION PROBABILITY VALUES



Values of  $\chi^2_\alpha$

v	$\chi^2_{.995}$	$\chi^2_{.99}$	$\chi^2_{.975}$	$\chi^2_{.95}$	$\chi^2_{.90}$	$\chi^2_{.10}$	$\chi^2_{.05}$	$\chi^2_{.025}$	$\chi^2_{.01}$	$\chi^2_{.005}$
1	.000039	.00016	.00098	.0039	.0158	2.71	3.84	5.02	6.63	7.88
2	.0100	.0201	.0506	.1026	.2107	4.61	5.99	7.38	9.21	10.60
3	.0717	.115	.216	.352	.584	6.25	7.81	9.35	11.34	12.84
4	.207	.297	.484	.711	1.064	7.78	9.49	11.14	13.28	14.86
5	.412	.554	.831	1.15	1.61	9.24	11.07	12.83	15.09	16.75
6	.676	.872	1.24	1.64	2.20	10.64	12.59	14.45	16.81	18.55
7	.989	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48	20.28
8	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.53	20.09	21.96
9	1.73	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67	23.59
10	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21	25.19
11	2.60	3.05	3.82	4.57	5.58	17.28	19.68	21.92	24.73	26.70
12	3.07	3.57	4.40	5.23	6.30	18.55	21.03	23.34	26.22	28.30
13	3.57	4.11	5.01	5.89	7.04	19.81	22.36	24.74	27.69	29.82
14	4.07	4.66	5.63	6.57	7.79	21.06	23.68	26.12	29.14	31.32
15	4.60	5.23	6.26	7.26	8.55	22.31	25.00	27.49	30.58	32.80
16	5.14	5.81	6.91	7.96	9.31	23.54	26.30	28.85	32.00	34.27
18	6.26	7.01	8.23	9.39	10.86	25.99	28.87	31.53	34.81	37.16
20	7.43	8.26	9.59	10.85	12.44	28.41	31.41	34.17	37.57	40.00
24	9.89	10.86	12.40	13.85	15.66	33.20	36.42	39.36	42.98	45.56
30	13.79	14.95	16.79	18.49	20.60	40.26	43.77	46.98	50.89	53.67
40	20.71	22.16	24.43	26.51	29.05	51.81	55.76	59.34	63.69	66.77
60	35.53	37.48	40.48	43.19	46.46	76.40	79.08	83.30	88.38	91.95
120	83.85	86.92	91.58	95.70	100.62	140.23	146.57	152.21	158.95	163.64