RADIOGRAPHIC EQUIPMENT SET

Army Test and Evaluation Command
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U. S. ARMY TEST AND EVALUATION COMMAND
DEVELOPMENT TEST II (ET) - SYSTEM TEST OPERATIONS PROCEDURES

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SECTION I GENERAL

1. Purpose and Scope. This TOP provides guidance in the writing of test plans for radiographic equipment sets to assure conformance with ROC's, MN's, and other guidance documents. From the subtests listed in section II, the test director can select those that will satisfy the requirements for the particular test item and test type (i.e., development test II (ET), development test III, etc.). This pamphlet covers simulated environmental tests but does not include development tests II (ST) or environmental tests at climatic test sites. All portable radiographic equipment, other than medical, is covered. This includes conventional X-ray units that employ an electrically energized X-ray tube to produce X-rays; and source units that utilize a radioisotope (also called gamma ray source) to produce gamma rays suitable for radiography.

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13. ABSTRACT

Describes a method for evaluation of radiographic equipment operational and functional performance characteristics. Identifies supporting tests, facilities, and equipment required. Provides procedures for safety, operator training, initial inspection, physical characteristics, performance, environmental, transportability, durability, human factors, and reliability testing. Applicable to portable radiographic equipment used in evaluation of structural integrity and interior constitution of weldments, vehicle structures, castings, and assemblies such as ammunition fuzes and dud rounds. Excludes medical equipment and test at climatic test sites.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Radiographic equipment Set*						
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2. Background.

a. Radiographic equipment is used to provide information on structural integrity and interior constitution of weldments, vehicle structures, castings, and assemblies such as ammunition fuzes and dud rounds. These machines produce X-ray or gamma ray energy which passes through materials, being partially absorbed by matter in proportion to its density and atomic number. By placing film sensitive to X-ray energy on one side of the object being examined, and the X-ray projector on the other, a record of variations in material density and atomic number are recorded on the film as variations in film density or blackening. Metal assemblies appear transparent, and details of interior construction are visible without the necessity for disassembly and inspection. Cracks and voids in welds and castings appear characteristically as lines or spheroidal shapes of greater film densities than surrounding areas. Military specifications provide comparison X-ray films for rating weldments and castings.

b. Conventional X-ray equipment, which involves applying electrical energy in the kilovolt range to an X-ray tube for a certain length of time, is best for most applications. Such equipment is expensive, however, and requires a power source. For special applications, it may be advantageous to use a radioisotopic source, usually cobalt-60, which is housed in a shielded container. To serve as a radiographic source, the radioisotope is moved by hand-cranking along a cable to its proper location. The unit is often called a gamma ray projector.

3. Equipment and Facilities. Equipment and facilities are covered in the references of section II.

SECTION II
TEST PROCEDURES

4. Supporting Tests. Subtests (in preferred order of completion with respect to high risk, short duration) to be considered in formulating a development test II (ET) plan, with TOP/MTP's, Military Specifications, and other references, are as follows:

	TEST SUBJECT TITLE	PUBLICATION NO.
a.	Operator Training and Familiarization (refer to para 6)	MIL-R-11470A; 10 CFR, part 34
b.	Initial Inspection (refer to para 7)	
c.	Physical Characteristics (refer to para 8)	10-2-500
d.	Safety Evaluation	
	(1) General and Electrical	10-2-508

TEST SUBJECT TITLE	PUBLICATION NO.
(2) Radiation (refer to para 9)	AMCR 385-25; 10 CFR, part 34; NBS Handbooks 41, 59, 93

e. Performance Tests

(1) Radiation Leakage (refer to para 10)	
(2) Sensitivity (refer to para 10)	
(3) Quality and Quantity of Radiation (refer to para 10)	
(4) Focal Spot Size	FED-STD-83
(5) Duty Cycle (refer to para 10)	
(6) Dielectric Strength (refer to para 10)	

f. Shock Resistance (refer to para 10)

g. Environmental Tests (refer to para 11)

h. Transportability (refer to para 12) 1-2-500, 1-1-050

i. Human Factors Evaluation (refer to para 14)

j. Reliability (refer to para 15)

k. Maintenance Evaluation *10-2-507

*To be replaced by TOP 1-2-501.

SECTION III
SUPPLEMENTARY INSTRUCTIONS

5. Safety of Test Operations

a. Radiographic testing is performed in an area that can be shielded or excluded to prevent access by nonauthorized personnel. A dose rate of less than 2 mr/hour must be insured for all nonexclusion areas.

b. All Department of the Army personnel using radiographic equipment utilize the Army film badge service in accordance with AR 40-14, paragraph 6c. In addition, such personnel are equipped with direct-reading pocket dosimeters from which daily readings are recorded.

c. At least one calibrated and operable radiation survey meter will be available and turned on during radiographic exposures. This meter must be sensitive to, and calibrated in the energy range of, the radiographic equipment. The meter is used to check for radiation leakage and to monitor the positions where personnel are located.

d. Exposure of radiographic equipment operators is limited to a maximum ionizing radiation dose of 5 rems/year (ref. 1, appendix). Local regulations often are much more restrictive and must be observed. During testing of radiographic equipment every effort should be made to hold radiation levels as close to zero as practicable. Use of shielding materials, collimation of the X-ray beam, and use of as great a distance as possible between operator and tubehead or radioisotopic source are means of minimizing operational exposures. Test plans should include due consideration of all reasonable means of minimizing radiation exposure of operating personnel.

e. Radiographic units are used strictly within the operating parameters recommended by the manufacturer. Two radiation exposure hazards are present: (1) direct beam and (2) indirect or scattered radiation. The first will be avoided by operators at all times by the use of positive means of equipment shutdown and continuous use of radiation detection devices to insure that the beam is OFF when operators are exposed. The second, scattered radiation, may cause some operator exposure when the machine is on or the source is out. Under normal operating conditions a certain amount of radiation leakage exists, spelled out as a maximum in the manufacturer's specifications. This may be reduced by the use of beam collimation, additional shielding such as lead aprons and gloves, use of maximum distance between operator and source, and by use of the shortest possible radiographic exposure times.

f. Adequate health and safety supporting equipment is used including survey instrumentation, warning signs, and cordons. These means should insure that nonoperational personnel are excluded from areas where the dose rate is 2 mr/hour and greater.

6. Operator Training.

a. The operation of the radiographic equipment should be entrusted to personnel already familiar with the operation of X-ray equipment as part of their normal assignment. Such personnel are, however, required to become familiar with the specific item of equipment through applicable technical manuals, manufacturer's literature, etc.

b. A special facet of the training is related to radiation safety. All personnel who will operate or assist in the operation of radiographic equipment must be educated in the associated radiation hazards. The Army, Atomic Energy Commission, and U. S. Public Health Service offer training on radiation safety.

7. Initial Inspection. The initial inspection is conducted to determine the condition of the radiographic unit upon arrival to assure that it is complete, undamaged, and acceptable for testing. It is particularly important to have knowledge of the original condition of the components when a failure occurs later during test operations. Among the points to check are the following:

a. Condition of crates and packages; specifically, the adequacy of the packaging, damage to packaging, and problems in uncrating.

b. Condition of radiographic unit; specifically, workmanship defects; transportation damage; construction, finish, or materials defects; and signs of corrosion.

c. Adequacy of maintenance test package (TOP 1-2-501), including manuals, spare parts, and tools.

8. Physical Characteristics. In addition to the measurement of the physical characteristics (TOP/MTP 10-2-500), a characteristics photograph is prepared which, on one full-size page, shows an overall picture of the item together with a listing of its major physical and performance characteristics. The characteristics photograph is suitable both for the report and as a separate, handy reference.

9. Safety Evaluation.

a. There are two principal elements of the safety evaluation subtest: (1) general and electrical safety as covered by TOP/MTP 10-2-508 and (2) radiation safety as covered below and in AMCR 385-25; Title 10, CFR, part 34; and NBS Handbooks 41, 59, and 93.

b. A Safety Statement will be available to the test director prior to commencing the development test II (ET), as required by TECR 385-6.

c. A check is made to assure that adequate ancillary equipment related to radiation safety is provided with the radiographic set. This includes a radiation survey meter, pocket dosimeters (or film badge instructions, when more appropriate), radiation warning signs, material for cordons, and safety instructions. Each of these should be checked for adequacy.

d. Radiographic units are checked to insure that leakage does not exceed the limit specified, and radiation levels are mapped in various directions during typical radiographic operations. Portable radiation survey instruments may be used to make this check provided they are calibrated in the energy range of the radiation to be detected. The location of radiation leaks and a general indication of their radiation intensity may be obtained by covering the radiation head with X-ray film, operating the radiographic unit, and then examining the exposed file for evidence of excessive leakage radiation.

e. X-ray machines and radioactive source projectors should be equipped with "X-ray On" or "Source Exposed" indicator lights. Instructions should state that a least one survey meter should also be used to insure that the primary radiation beam is off before personnel are exposed.

10. Performance Tests. The performance tests described below are based upon those contained in the procurement specifications referenced in the appendix.

a. Radiation Leakage.

(1) With the X-ray system operating at full rated kv and ma settings, the indirect radiation from the X-ray head shall not be greater

than the specified maximum value in mr/hour except in the direct beam. When not specified, this value is usually a maximum of 200 mr/hour at a distance of 25 feet from the tubehead.

(2) Indirect radiation leakage is measured by placing a lead sheet of sufficient thickness to greatly attenuate the energy in the direct beam as close as possible to the radiation source (e.g., 1/4-inch thick for 300-kv X-rays). Measurements are then made with a radiation survey meter at a distance of 25 feet.

(3) Similar measurements may be made on a gamma ray source by running the radioactive source out to the end of its projector cable, into a shielded collimator, and blocking the exit part of the collimator with lead sheet, as above. If the unit does not include a collimator head, then only leakage measurements of the source in place in its storage pig need be made. Leakage in this latter case must not exceed the values shown in Title 10, CFR, Part 34.

b. Sensitivity.

(1) The radiographic unit shall be capable of showing the specified penetrameter hole in the specified thickness penetrameter, the penetrameter being of the same material as the specified test block, with the X-ray tubehead or source placed at the required film focal distance.

(2) MIL-R-11470A gives parameters for various sized X-ray machines and gamma ray projectors. Federal and military specifications such as GG-X-625, GG-X-630, MIL-X-81383, MIL-X-19685A, and MIL-X-19847A list requirements for specific X-ray machines.

(3) Minimum acceptable penetrameter sensitivity is usually 1 or 2 percent for X-ray machines and 2 to 3 percent for gamma ray projectors. ASTM E142 and MIL-STD-453 give specifications and instructions for the use of standard penetrameters. Penetrameters must always be placed on the same side of the test plate as the radiation source, near the edge of the effective beam-spread.

c. Quality and Quantity of Radiation.

(1) The radiographic unit shall be capable of producing a gross Hurter and Driffield (H&D) density as specified through the specified thickness of material at a specified film focal distance, on specified film in the specified time when operating at full output kv and ma; or, a specified output in roentgens per minute measured at a specified distance from the tubehead, in the center of the direct beam. Roentgen output behind a specified metallic filter may be measured in lieu of the above (see MIL-X-81383 for an example of the above requirements).

(2) Direct radiation measurements shall be made with a calibrated radiation measuring instrument such as a condenser R-meter.

d. Duty Cycle.

(1) The X-ray unit shall be capable of operating on a specified duty cycle at an ambient temperature of not less than 72° F. A temperature measuring device such as a calibrated thermometer or a thermocouple shall be attached to the hottest portion of the tubehead. The apparatus shall be operated on the required duty cycle. Ambient temperature and the tubehead temperature shall be measured immediately following an ON cycle and just prior to starting an ON cycle. Failure of the apparatus to continue the established cycle or failure to level the temperature-time curve shall be cause for rejection.

(2) Gamma ray projectors are by nature 100 percent duty cycle and do not require the above testing.

e. Dielectric Strength.

(1) The X-ray system shall be capable of withstanding an overvoltage in an amount and time specified. There shall be no evidence of dielectric breakdown or the inability to attain and maintain the test potential. The assembled X-ray system shall be subjected to the specified test voltage between each of the two power prongs of the power cable (excluding the third, or ground, prong) and the control panel case and the X-ray head assembly case (for a total of four tests). During this time, the line switch shall be in the ON position and the relative humidity shall not exceed 50 percent.

(2) The above testing is not appropriate for gamma ray projectors.

11. Environmental Tests. The purpose of these tests is to determine the ability of the test item and its components and accessories to resist physical damage and deterioration when subjected to stipulated extreme climatic and environmental conditions. Testing should be conducted as necessary to ensure that the test item is capable of operating satisfactorily under conditions existing within the operating areas and environments specified by the applicable ROC's and defined by AR 70-38 or the procurement specification. In the preparation for testing, the test engineer should be particularly aware of the exact conditions under which the equipment is designed to operate.

a. High Temperature and Solar Radiation Tests. The test item is exposed to conditions of high temperature as established by the applicable ROC or specifications. Unless otherwise indicated, it will be assumed that the equipment must be able to operate and sustain storage in accordance with the intermediate conditions of AR 70-38. The high-temperature test will include exposure to simulated solar radiation in a cycle defined by AR 70-38.

b. Low Temperature Test. The test item will be exposed to the low temperature limits as established by the applicable ROC or specifications.

Unless otherwise indicated, low temperatures will be in accordance with the intermediate conditions of AR 70-38; that is, storage at -30° F. and operation at -25° F.

c. Dust Test. The test item is subjected to a dust test in accordance with MIL-STD-810B, method 510. Additionally, items that may be operated a few inches above the ground should be subjected to a blowing sand test. (See TOP 3-2-045 for a formulation.)

d. Rain Test. The test item is subjected to a rain test in accordance with the applicable procedures of MIL-STD-810B, method 506. The test item must be able to operate following exposure.

e. Humidity Test. The test item is exposed to the 10- or 20-day cycling test described in MIL-STD-810B, method 507, procedure V. The test item must be able to operate during exposure and immediately following exposure.

f. Salt Spray Test. A 24-hour salt spray test in accordance with MIL-STD-810B, method 509 is conducted on the test item and accessories. Following completion of the test, each item is inspected for corrosion and the item operated. Corrosion and mechanical or electrical problems are recorded.

12. Transportability. Transportability for radiographic units involves three different phases: shock resistance, including rough handling; transportation vibration; and compatibility with mounting vehicle. Other factors to be considered in regard to transportability are contained in TOP 1-2-500.

a. Shock Resistance.

(1) In the shock resistance test the complete X-ray or gamma ray unit is first operated at full performance capacity (to include a check of the operation of the projection tube for a gamma ray source) to obtain baseline data. The X-ray tube housing is then raised 2 feet (measured from the bottom edge), inclined at an angle of 45°, and dropped once (with or without the tube in place) on a concrete or 1-inch-steel slab.

(2) The X-ray unit is then operated at full power, for full duty cycle, for a period of 2 hours. Temperature at the surface of the X-ray tube housing opposite the high voltage transformer winding, and the ambient temperature are measured at the start and end of this electrical test.

(3) A gamma ray projector is visually inspected and checked for mechanical operation by moving the source out and in through the projector tube after shock testing.

b. Transportation Vibration. The transportation-vibration test is conducted in one of two ways. If the item is reasonably small, it can be vibrated in its shipping container in accordance with TOP/MTP 4-2-804 (to be replaced by TOP 1-1-050). If it is large, it will have to be transported in its transporting vehicle (a trailer) over test courses in accordance with the schedule of TOP 2-2-506.

c. Compatibility With Mounting Vehicle. The test to evaluate compatibility with mounting vehicle is conducted by mounting the unit in its transporting trailer and performing the trailer tests outlined in TOP/MTP 2-2-525. Following the testing the equipment is examined for damage and operated.

13. Durability and Endurance.

a. The durability of an item is related to the statistical probability that the item will attain its planned life without a durability failure (e.g., a failure that would require a major overhaul). Because of the large number of samples that would be required to determine durability (TOP 1-2-502), it is unlikely that a durability test will ever be required for a radiographic unit.

b. Endurance is a general term that describes the ability of the item to operate for long periods of time without significant failures. There is no need for a separate endurance subtest for radiographic units since the information can better be expressed by applying the reliability subtest.

14. Human Factors Evaluation. During all testing, the test item is evaluated for its compatibility with man. This includes, but is not limited to, ease of access and manipulation of controls and switches and, for a gamma ray projector, the projector handcrank. Indicating lights and dials should be clearly visible and markings should be easy to read. Location and shape of carrying handles for portable components should be evaluated, as well as weight and handling characteristics of these items.

15. Reliability.

a. For a proper evaluation of reliability (maintenance evaluation as well) the test item must be operated for considerable periods of time and on many distinct occasions, the exact number of hours of operation and number of occasions of operation being dependent upon the reliability requirements as stated in the ROC or specification. In general, however, the failure distribution is assumed to be exponential, that is, a constant failure rate exists. Under such conditions, usually an MTBF (mean time between failures) is stipulated. Confidence limits on this parameter can be computed using appropriate percentage points of the chi-square distribution. Sometimes, however, the reliability is expressed

in terms of a mission reliability, in which case the mission will be defined in the guidance document. To determine mission reliability, the mission must be repeated a number of times, as determined by statistical techniques, and successes and failures be appraised using the binomial distribution. Mission reliability is particularly important for radiographic sets because of the significant amount of actions that are involved in startup and shutdown.

b. Data accumulated during the reliability subtest are also applicable to the maintenance evaluation subtest. All failures and the operating hours accrued at time of failure are recorded. This will include all failures and operating hours that occurred during other test phases except hours accrued during exposure to extreme environments and failures attributed to these environments.

c. Reliability criteria usually are contained in ROC's, MN's, etc. In the absence of such criteria, recourse is made to data generated in previous testing of similar items. There should be no significant degradation in the reliability of the item being tested compared with the reliability of the previously tested item; in other words, the test item should not be less reliable than the system being replaced. Before testing, a definition of a failure must be established, preferably from guidance documents. If no such definition exists, a failure will be defined as any malfunction which the operator cannot remedy by adjustment, repair, or replacement action, using the controls, OEM tools, and OEM parts, within 30 minutes and which causes or may cause:

(1) Failure to commence operation, cessation of operation, or appreciable degradation of performance of the unit.

(2) Serious damage to the unit.

(3) Serious personnel safety hazards.

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APPENDIX
REFERENCES

1. Title 10, Code of Federal Regulations, Part 34, "Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations."

2. Army Regulations (AR):

   40-14, "Control and Recording Procedures, Occupational Exposure to Ionizing Radiation."

   70-38, "Research, Development, Test, and Evaluation of Materiel for Extreme Conditions of Environment."

   700-52, "Licensing and Control of Sources of Ionizing Radiation."

3. AMCR 385-25, "Safety - Radiation Protection."

4. AMCR 715-501, Vol I, "Radiography."

5. TECR 385-6, "Verification of Safety of Materiel During Testing."

6. TECR 750-15, "Maintenance Evaluation During Testing."

7. TB ORD 1034, "Inspection of Materiel: Radiographic Method."

8. FED-STD-83, "X-Ray Tube Focal Spot, Method of Measurement."

9. MIL-STD-453, "Inspection, Radiographic."

10. MIL-STD-810B, "Environmental Test Methods."

11. Fed Spec GG-X-625, "X-Ray Apparatus, Radiographic, Mobile, 100 Ma."

12. Fed Spec GG-X-630, "X-Ray Apparatus, 15 Ma, For Use In Explosive Atmospheres."

13. Military Specifications:

    MIL-R-11470A, "Radiographic Inspection: Qualification of Equipment, Operators and Procedures."

    MIL-X-19685A, "X-Ray Apparatus, Radiographic, Industrial, Spot, Portable, 140 Kvp."

    MIL-X-19847A, "X-Ray Apparatus, Radiographic, Industrial, Portable, 120 to 250 Kvp Rating."

    MIL-X-50282, "X-Ray System."

MIL-X-81383, "X-Ray Apparatus, Radiographic, Industrial, Lightweight, Portable, 140 Kvp Rating."

14. National Bureau of Standards (NBS) Handbooks:

41, "Medical X-Ray Protection up to 2,000,000 Volts."

59, "Permissible Dose From External Sources of Ionizing Radiation."

93, "Safety Standard for Nonmedical X-Ray and Sealed Gamma Ray Sources."

15. ASTM-E142, "Method of Controlling Quality of Radiographic Testing," American Society for Testing Materials.