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This document describes general procedures for corrosion and degradation tests of materials and materiel systems in humid tropic environments.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP 702-100
Test Operations Procedure (TOP) 1-1-061 4 November 1987
AD No.

CORROSION AND DETERIORATION TESTING IN HUMID TROPIC ENVIRONMENTS

1. SCOPE. This test operations procedure describes general procedures for corrosion and degradation tests of materials and materiel systems in humid tropic environments.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Laboratory facility	To measure physical properties of test material/materiel and to store control items under controlled environmental conditions
Meteorological site	Instrumentation to collect data must be near test item/materials
Exposure racks	To securely anchor/expose test material/materiel at specific heights and angles
Sample holders	To support test specimens in exposure racks

ITEM (cont.)	REQUIREMENTS (cont.)
Exposure sites*	To expose materiel/material to selected natural humid tropic environments

*Exposure sites will be selected based on the expected environmental condition in which the test item will be used. Generally, selection of exposure sites should be made in the most severe yet most realistic natural environment available to increase the chances of detecting material/materiel problems. Environmental parameters normally considered for site selection include the following:

Daily temperature (high, low, mean)
Humidity (high, low, mean)
Rainfall (monthly, daily)
Vegetation description (types, stem size, density and height)
Solar radiation (intensity)
Soil (type)
Wind (direction and speed)
Salt content of air (chloride)
Microbial activity (levels)
Insect activity (types and levels).

2.2 Instrumentation.

a. Field instruments. Accuracy of the following instruments depends upon specific test requirements which should be addressed during test planning.

DEVICES FOR MEASURING

Air temperature (e.g., thermometer, thermocouples or thermistors)

Surface temperature (e.g., pyrometer)

Relative humidity (e.g., psychrometer - aspirated, sling or hair)

Rainfall (e.g., rain gauges)

Solar radiation (e.g., pyranometer and radiometers)

Wind speed (e.g., anemometer)

Wind direction (weather vane)

Salt content of air (e.g., salt candles)

Sample weight changes (e.g., scales, analytical balances, etc.)

Visual sample changes (e.g., 35mm camera)

Distances (e.g., rangefinder)

Headings (e.g., lensatic compass)

DEVICES FOR MEASURING (cont.)

Sample surface examinations (e.g., 60-power pocket microscope)

Sample measurements (e.g., micrometers)

Dimensions (e.g., tape measure)

Durability (e.g., dynamic testers)

Color changes (e.g., color chart)

Microbial presence (samplers--liquid, solid, biological)

Ozone, nitrous oxide, hydrocarbons, sulfur compounds (e.g., environmental pollutant meters)

b. Laboratory instruments. Selected procedures for measurement of material characteristics will determine the required instruments for the exposure test. Required accuracy of these instruments usually will be given by selected standard procedures, e.g., American Society for Testing and Materials (ASTM) standards or Federal Test Method (FTM) standards and should be addressed during test planning.

DEVICES FOR MEASURING

Changes in tensile strength, elasticity, and elongation of materials (e.g., tensile/compression instrument)

Surface deterioration, fungal growth and contamination (e.g., optical, electron microscopes)

Material surface and subsurface flaws (e.g., nondestructive inspection equipment)

Thickness, length, width, depth, inside/outside diameters, and other physical dimensions (e.g., micrometers)

Precise weight of test materials (e.g., analytical balances)

Identify inorganic materials such as corrosion products (e.g., X-ray diffraction)

Identify chemical changes on surface of organic materials (e.g., infrared spectrophotometer)

3. REQUIRED TEST CONDITIONS.

3.1 Test Planning. Establish the scope and objective(s) of exposure tests. For example, the tests may be planned to permit reporting any of the following:

a. Changes in the physical properties of materials or items after a specified exposure period.

b. Exposure time dictated by tactical doctrine for specific systems.

c. Exposure time to the occurrence of a specified physical change in material samples, or of a specific event such as exposure to a specified amount of solar radiation.

d. Degradation profile, namely a record of a series of measurements of changes in physical characteristics after specified exposure periods.

e. Observation of a specific component or group of components in a materiel system known to have suffered environmental deterioration in a previous test.

f. Establish fixed procedures for preparing, conditioning, and cleaning items. The procedures will vary with materials, but must be uniform to provide comparative results.

g. Establish laboratory methods and procedures for measurement of item characteristics. When available, standard methods and procedures should be employed such as Federal Test Method (FTM) and American Society for Testing Materials (ASTM) standards.

h. Determine required instrumentation and its accuracy for measurement of material/materiel characteristics in accordance with selected methods and procedures.

i. Design data collection sheets for collection of field and laboratory test data.

j. Establish a corrosion/deterioration checksheet to be used throughout all phases of testing, from receipt to final inspection. Use the checksheet as a guide during visual inspection of the exposed material sample or item. The item or system should be examined to determine exactly what components or areas are to be inspected and what kinds of deterioration to expect. Specific areas for concern include the following: areas which entrap water (corrosion or blistering of coatings), areas which retain dirt or debris (corrosion, blistering of coatings, fungal attack), areas where dissimilar metals are in contact (galvanic corrosion), seams or crevices (crevice corrosion, coating defects, galvanic corrosion), high temperature areas (burned or damaged coatings, corrosion), damaged coatings (blistering, chalking, corrosion), mechanical damage (corrosion of unprotected surfaces, loss of camouflage), areas exposed to chemicals (battery boxes, human contact points, etc., corrosion and blistering of coatings), and electrical components (water intrusion, galvanic corrosion, fungal growth).

k. For microbiological inspections, an evaluation schema similar to that described in MTP 5-2-584[1] should be used. The item or system should be examined to determine exactly what components or areas are to be inspected and what kinds of deterioration are expected.

l. Establish length of the exposure; duration of exposure is determined by the requirement of the individual test and the item being tested. For example, materials such as ceramics deteriorate slowly over a period of years while unprotected carbon steel may be completely destroyed within 8 weeks.

m. Establish a field inspection schedule and a sample retrieval schedule. An appropriate schedule is critical to the test. The schedule is determined by the severity of the exposure site, the degradation characteristics of the material, test duration, and test objectives. The schedules in Table 1 are based on exposures at Tropic Test Center sites and are intended for general guidance only. Actual exposure periods may be much longer.

n. Estimate total sample size required to meet the test objectives. Estimation should be based on the test requirements, exposure duration, retrieval/inspection schedule, type of laboratory test (destructive/nondestructive), repeatability of measurement techniques, expected material deterioration patterns and prior knowledge of material homogeneity. Sample size must include a sufficient number of samples to serve as control samples.

o. Establish the experimental design and statistical analyses proposed for addressing the objectives of the exposure test.

p. Prepare test operations and inspection checklists using the checklist provided in Appendix A and systems manuals as guides. The test operations checklist should cover specifics for the test item/material and test milestones.

TABLE 1. TEST SITE EXPOSURE SCHEDULES

Material	Minimum Exposure Time	Inspection Schedule
Carbon steel (unprotected)	8 weeks	Weekly
Cotton fabric	1 year	Biweekly first 8 weeks, monthly thereafter
Plastics (polyvinyl chloride and nylon)	1 year	Biweekly first 8 weeks, monthly thereafter
Vehicles/artillery	1 year	Monthly
Ammunition/missiles	1 year	Monthly
Fabric structures	6 months	Biweekly first 8 weeks, monthly thereafter
C^3I equipment	6 months	Biweekly first 8 weeks, monthly thereafter
General clothing and equipment	6 months	Biweekly first 8 weeks, monthly thereafter

3.2 <u>Test Site Selection</u>. The U.S. Army Tropic Test Center (USATTC), Fort Clayton, Panama, has a number of sites available for exposing items. These sites provide various tropic macro-environments, each one having peculiar conditions which accelerate specific environmental effects. The appropriate exposure site should be selected based on the unique requirements of the test item. A brief description of the general environmental conditions at each site is presented in Appendix D. A number of different micro-environments may also be found at each exposure site. These should be considered when selecting a specific location within the selected site, because each micro-environment may affect the material/item differently. Therefore, all micro-environments present at any site should be considered in site selection during test planning.

3.3 Exposure Mode Selection. Depending on intended use or storage, materiel/material being tested may be exposed in any of the following modes which characterize various degrees of exposure to ambient conditions:

a. Direct exposure -- exposure to all prevailing atmospheric elements.

b. Open shed -- exposure under a roofed structure with open sides permitting free air flow but not subject to direct sunlight and rainfall.

c. Covered -- normally, exposure on a pallet with the test items covered with a tarpaulin to exclude direct sunlight and rainfall. This is an accelerated method which gives high induced temperatures and reduced evaporation of moisture.

d. Warehouse -- exposure in a building, tent, or bunker.

4. TEST PROCEDURES.

4.1 Procedures for Materiel System Tests.

4.1.1 Facilities. Sites for testing materiel systems for corrosion/deterioration resistance include the full range of humid tropic environments described in AR 70-38[2] as Constant and Variable High Humidity Daily Cycles of the Basic Climatic Design Type. They include forested sites of classic jungle vegetation where temperatures are virtually constant day or night throughout the year at about 24°C with relative humidity constantly at 94-100% with occasional drops to 80%. Open test areas (inland, coastal and breakwater) vary in temperature throughout the day from about 21 to 36°C, with relative humidity levels that range from saturation at night to about 75% during the hottest part of the day. Coastal and breakwater sites have high levels of atmospheric salt fall that combine with the high temperature and relative humidity levels to produce an environment that is extremely corrosive to metals. Intense solar radiation in open areas and high levels of biological activity in forests produce rapid degradation of susceptible nonmetallic materials. Sites should be selected with the military use of the item in mind.

4.1.2 Receipt Inspection. This serves a twofold purpose: to document the condition of the item or system as received for testing, and to assist in formulating inspection procedures after the item has been stored or performance tested. Careful attention must be given to areas of preexisting corrosion, as well as areas which may ultimately suffer attack. (See para 3.1j.) The appropriate operation/maintenance manuals for the item or system must be reviewed for prescribed inspections, but receipt inspection will not necessarily be limited to these areas.

4.1.3 Performance/Exposure Testing. Deterioration will progress at varying rates during performance testing and also during storage or exposure. Sufficient time must be allowed for potential degradation to become observable and to give evidence of its ultimate effects on performance, structural integrity, and durability in general. Regularly scheduled inspections will identify degradation soon after it occurs and allow reasonable estimates of its impact on the item. Specific details for inspection schedules will appear in the test plan. Guidance is given in Table 1 above. Initial appearance and significant advances or changes in degradation should be documented in test incident reports (TIRs) as well as in the test officer's logbook for inclusion in other reports.

4.1.4 Final Inspection. This is the climax of the test as far as corrosion and other deterioration are concerned. This inspection must be done diligently and with extreme attention to detail, since it is the last chance to document potential problems with the test item. Again, all areas that have the potential for corrosive or deteriorative attack (See para 3.1j.) must be inspected and each type of attack and its location carefully documented.

4.1.5 Suggested Improvements. When corrosion or any degradation is observed, an attempt should be made to analyze the failure or deterioration to avoid the problem in the future. Where possible, it is incumbent upon test personnel to suggest improvements in item design, materials, or protection schemes to enhance the life or serviceability of the item. Suggestions will be placed in TIRs or final reports.

4.1.6 Data Required.

a. Ambient temperature (minimum, maximum, average (mma))

b. Relative humidity (mma)

c. Wind speed (mma)

d. Wind direction (hourly)

e. Solar radiation (total, horizontal/vertical, wavelength intensity)

f. Rainfall (total and intensity)

g. Salt fall (total), as required

h. Other air contaminants, as required

i. Corrosion/deterioration observed by using corrosion/deterioration checklist developed from paragraph 3.1j.

4.2 Procedures for Material Sample Exposure Tests.

4.2.1 Facilities.

a. Exposure site.

(1) Measure and record appropriate environmental conditions.

(2) Install exposure rack(s). The area beneath the racks should be typical of the ground cover at the site.

b. Install selected instrumentation for measurement of climatological data at the meteorological site.

c. Exposure rack design depends on the size and characterization of the test material. Racks and associated hardware should be constructed of materials that are highly resistant to corrosion. Aluminum alloy No. 6061-T6 and Monel are recommended as construction materials. Generally the racks should be designed to position the exposed surfaces of the material samples at an angle of 30° to the horizontal facing east. For some materials other orientations such as vertical or horizontal may be required. The exposure rack should not constitute a backing for the samples. The rack should be designed so that the lowest samples positioned on the rack are exposed at a minimum height of 76cm above ground level, unless otherwise required by the expected use of the test material.

d. Sample holders should be constructed of an inert material, such as ceramic insulators, aluminum extruded shapes and Plexiglas strips. The sample holders should be designed so that the specimens cannot shift position, yet not be constrained (i.e., be free to expand or contract with thermal changes, to swell from moisture absorption, or to shrink because of plasticizer loss). The geometric shape, expected static or dynamic stress use/conditions, physical size, weight, flexibility and resistance to air flow of the samples must be considered in the selection of the sample holders. Unless specified by the design, the sample holder should not constitute a backing for the portion of the material to be evaluated.

4.2.2 Instrumentation. Ensure that all field and laboratory instruments are calibrated in accordance with AR 750-25.[3]

4.2.3 Test Samples.

a. Test samples should be procured from the same material lot to optimize homogeneity. The samples should be prepared and conditioned identically in accordance with selected procedures (para 3.1f).

b. Exposure test samples may be of any size or shape that can be mounted in a holder directly applied to the racks or as specified by the appropriate test design. The specimens must be of sufficient dimension from which suitable samples may be cut for evaluation. Exposure test samples should be large enough so that mounting edges can be removed if evaluation test results would otherwise be affected.

c. Normally, all materials of unknown end-use application will be exposed in an unbacked condition. Backing shall be used only to simulate an end-use system rather than as a standard mounting method. The effect of backing is highly significant and may contribute to the degradation as a function of reflectance and heat absorption. When conditions of use are known, the sample exposed will be emplaced in a manner that conforms to proposed use.

d. All test samples should be marked with appropriate identification which must remain legible throughout the exposure period. The rack itself and the position on the rack should be identified. After all samples are placed on the racks, the test officer should have a detailed sketch or photographic record of the completed rack with all the appropriate markings and identifications.

e. The specimens to be removed after each retrieval interval should be determined before their exposure. These specimens should be exposed randomly on different racks to ensure a representative exposure.

f. Packaging is an important factor to be considered before exposing the material. The packaging method should not damage or alter any properties of the specimens while transporting the retrieved specimens back to the laboratories for detailed analysis. Preferably, each specimen should be wrapped individually in an inert envelope such as paper or plastic. When specimen surfaces are to be examined, soft, padded tissue should be used to wrap the specimens. Plastic bags may be sealed as appropriate. Desiccant packs must be used if the material is sensitive to humidity. Ship specimens by the fastest method available.

4.2.4 Control Samples. Basically there are two types of control samples - aged and unaged.

a. Unaged control samples are those material samples tested prior to any storage or exposure. The resulting test data are used as baseline data (zero time on the performance-versus-exposure time graphs) and for confirmation of the previous assumption of the degree of sample homogeneity used for estimating the total sample size required for the exposure test. The size of the sample allocated to this control group should be determined by a statistician experienced in experimental design. Based on the test results of the unaged control samples, modification of the sample-retrieval schedule or changes to the exposed sample size(s) may be required for achievement of the test objectives.

b. Aged control samples are those material samples stored at controlled standard conditions of 23° ±3°C and 50% ±2% humidity and covered with inert wrapping to exclude light exposure unless otherwise specified by test requirements. These samples are removed periodically from controlled storage and are tested in the laboratory along with exposed samples. Test data are used to identify the occurrence of nontropic deterioration effects and systemic errors in laboratory test procedures. Sufficient material samples should be allocated to this control group to obtain statistically significant test results. A statistician should be consulted for estimation of the required sample size. Aged control samples are also used for comparison purposes during field inspection of the exposed samples.

4.2.5 Test Controls.

a. Ensure that all sensors, recorders, and instrumentation are properly calibrated.

b. Ensure that clean plastic gloves are worn at all times when emplacing and removing material samples to avoid sample contamination.

c. Perform periodic inspections of the exposure site(s) to ensure materials are properly exposed in accordance with test design.

d. Procure test samples from the same material lot to optimize sample homogeneity.

e. Provide for unaged and aged controls samples (para 4.2.4).

f. Utilize random techniques for the following actions. (Consult a statistician for proper randomization procedures.)

(1) Sample selection from material lot

(2) Sample allocation (control and exposed samples)

(3) Sample emplacement on exposure rack(s)

(4) Sample retrieval from exposure rack(s)

(5) Laboratory testing of samples (control and exposed samples).

4.2.6 Test Method.

a. Install material samples on exposure racks in accordance with planned specimen layout (para 4.2.3).

b. Inspect the exposed material samples in accordance with the field inspection schedule (para 3.1j and Table 1).

c. Record data on Inspection Data Sheet(s) as shown in Appendix B. During field inspection exercise caution when inspecting the material samples; samples should not be disturbed unless specified by the test plan.

d Retrieve material samples in accordance with the retrieval schedule (para 3.1j and Table 1).

e. Package samples in accordance with established packing instructions (para 4.2.3f).

f. Transport samples to the laboratory expeditiously.

g. Perform laboratory tests on the retrieved samples to determine changes in physical properties. Perform laboratory tests concurrently on samples from the aged control group.

h. Record data on inspection or test data sheets.

i. Compile and analyze test data.

j. When appropriate, adjust field-inspection and sample-retrieval schedules as data are compiled and analyzed to obtain meaningful test results or to reduce test costs.

NOTE: Some exposure sites may be more or less severe to the specific items under test than originally estimated.

4.2.7 <u>Data Required</u>.

a. Test method documentation.

(1) Describe exposure site(s) and mode(s) to include the following:

(a) Soil (type)

(b) Vegetation--(type, stem size and spacing, and canopy height)

(c) Ground cover--(type in immediate vicinity of exposure racks)

(d) Slope of site (percent).

(2) Physical location of meteorological facility relative to test site(s).

(3) Description of exposure rack(s) and sample-holder construction.

(4) Orientation of exposure rack(s) to include the following:

(a) Rack elevation

(b) Exposure angle

(c) Rack azimuth.

(5) Method of mounting samples.

(6) Record of material sample layout on exposure racks.

(7) Description of material samples including photographs and identifying marks.

(8) Description of sample conditioning and cleaning procedures.

(9) Identification of laboratory test(s) to evaluate material deterioration.

(10) Identification of scoring standards for visual inspections.

(11) Results of laboratory tests of control specimens (baseline data).

(12) Exposure test duration.

(13) Field inspection and sample retrieval schedules.

b. Test results documentation.

(1) Daily meteorological data to include the following:

(a) Ambient temperature (minimum, maximum, average (mma))

(b) Relative humidity (mma)

(c) Wind speed (mma)

(d) Wind direction (hourly)

(e) Solar radiation (total, horizontal/vertical, wavelength/intensity)

(f) Rainfall (total and intensity)

(g) Salt fall (total), as required

(h) Other air contaminants, as required

(i) Corrosion/deterioration observed by using corrosion/deterioration checklist developed from paragraph 3.1j.

(2) Field inspection data for each material sample in accordance with Appendix B Inspection Data Sheet.

(3) Laboratory test data for each sample (measurements of physical properties of materials).

(4) Location, duration, and dates of exposure for each sample.

(5) Presence, extent, and identification of biological growth on the exposed samples, with estimate of effect on properties and serviceability of material.

(6) Material surface deterioration (visual and microscopic effects, chalking, roughness, crazing, corrosion, etc.).

5. PRESENTATION OF DATA.

a. Present the data outlined in paragraphs 4.1.6 and 4.2.7 in narrative, tabular, or chart format, as appropriate.

b. Compute the sample mean and standard deviations of the measured properties of the materials/items, and tabulate by exposure site, mode, and length of time.

c. Perform statistical tests to determine significance of changes in properties of exposed material, if appropriate.

d. Present graphs and photos for significantly different groups of data to show changes in properties versus exposure times or other parameters.

e. Analyze the data as required to determine whether observed changes in material properties are statistically related to specific environmental conditions.

Recommended changes to this publication should be forwarded to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TC-M, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity, Commander, U.S. Army Tropic Test Center, ATTN: STETC-MTD, APO Miami 34004. Additional copies of this document 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

SAMPLE TEST OPERATIONS CHECKLIST

Item	Yes	No	NA
1. Scope and objectives of exposure test established?	___	___	___
2. Exposure site(s) and mode(s) selected?	___	___	___
3. Methods and procedures selected for measurement of properties of items?	___	___	___
4. Scoring standards selected for visual inspections?	___	___	___
5. Field and laboratory instruments with required accuracy procured?	___	___	___
6. Length of exposure test and sample size determined?	___	___	___
7. Field inspection schedule established?	___	___	___
8. Sample retrieval schedule established?	___	___	___
9. Baseline data (control samples, para 4.2.4) collected and analyzed?	___	___	___
10. Exposure rack(s) and sample holder(s) constructed?	___	___	___
11. Meteorological site(s) established?	___	___	___
12. Required preparatory data (para 4.2.7a) recorded?	___	___	___
13. Items or samples emplaced at exposure site(s)?	___	___	___
14. Test milestones completed? (List test milestones by date; check off as accomplished.)	___	___	___
15. All modifications to initial test design documented?	___	___	___
16. Required test data (para 4.2.7b) recorded?	___	___	___

APPENDIX B

SAMPLE TEST INSPECTION DATA SHEET

PROJECT NO. ______________________

SITE ______________________

DATE ______________________

WEATHER CONDITION ______________________

INSPECTOR ______________________

SAMPLE NO. ____________ RACK NO. ____________

DESCRIPTION OF SAMPLE OR AREA EXAMINED (component, item, location on item, etc.) ______________________

____

1. General Appearance ______________________

   a. Surface nature (Describe.) ______________________

   b. Surface damage (if yes, type of damage) Yes____ No____
      Broken? Yes____ No____
      Cracks? Yes____ No____
      Scoring? Yes____ No____
      Crazing? Yes____ No____
      % of damage ______________

   c. Color--Compare exposed sample with aged control samples and describe differences. ______________
      If new color, identify using Munsell Color Guide. ______________

      ____

      Fading?. . . . . Yes____ No____

   d. Is sample. . . . . Transparent? Yes____ No____
      Translucent? Yes____ No____
      Opaque? Yes____ No____

   e. Appearance. . . . . Glossy____ Dull____

2. Debris (any foreign matter on sample):

   a. Percent top surface coverage ______________________

   b. Percent bottom surface coverage ______________________

   c. Color of ______________________

   d. Shape of ______________________

e. Imbedded in material? Yes____ No____
If no, is it loose? Yes____ No____
If yes, give depth.______% Coverage_______

f. Identify nature of debris. (Use of microscope is recommended.)

Salts? Yes____ No____
Corrosion products? Yes____ No____
Soil? Yes____ No____
Plant exudations? Yes____ No____
Seeds? Yes____ No____
Pollen? Yes____ No____
Spores? Yes____ No____
Algae? Yes____ No____
Insect eggs? Yes____ No____
Other? (Identify.) Yes____ No____

g. Collect debris for laboratory analyses.

3. Surface temperature (if required)____________________________

4. Corrosion.
Color(s) (Describe.)____________________________
Texture (Describe.)____________________________
Percent top surface coverage(s)____________________________
Percent bottom surface coverages(s)____________________________
Location(s) (Describe; use photographs or line drawings for clarity.)___
____
____

5. Condition (material sample exposure).

a. Is sample on the rack? Yes____ No____
If no, is it on the ground? Yes____ No____
(Identify.)____________________________
If no, is it missing? Yes____ No____

b. Is the sample damaged? Yes____ No____
If yes, by what and to what extent? (Describe.)______________
____

c. Is the rack damaged? Yes____ No____
If yes, by what and to what extent? (Describe.)______________
____

6. Other comments (e.g., changes in dimensions because of stretching, swelling, or shrinking)____________________________
____

APPENDIX C

IMPORTANCE OF ENVIRONMENTAL PARAMETERS

1. Temperature. The rate of chemical reactions increases as the temperature increases. Many microorganisms exhibit maximum growth when temperatures are between 24° and 36°C. Consideration should be taken to measure air and surface temperatures if the study is designed to develop cause-effect relationships.

2. Humidity. Condensation becomes a problem when the relative humidity approaches 100 percent. Water, as vapor, can diffuse into almost any container through pinholes or cracks and condense there. Water helps deteriorate materials by serving as the following:

A trap for nutrients for bacteria, fungi and other microorganisms.
A transport medium for chemicals.
A medium for chemical reaction.
A hydration agent for dry materials causing them to swell.

3. Rainfall. Tropical rainfall is usually a heavy downpour of relatively short duration. Two important effects on materials are as follows: Thermal shock due to rapid cooling caused by water on hot surfaces and wetting of surfaces, thus initiating corrosion processes. Rain water normally contains dissolved salts and is saturated with oxygen. This water provides an electrolytic path for corrosion propagation.

4. Vegetation. Some types of vegetation tend to exude tannins, sugars, and other natural plant products which may support microbial growth and corrosion processes.

5. Solar Radiation (to include ultraviolet radiation). Radiation can damage exposed samples causing cross linking and changes in polymeric structure and color. Solar radiation may damage heat sensitive items and cause softening of polymers and evaporation of solvents and plasticizers.

6. Soil Type. Soil chemistry and surface water influence corrosion processes of materials used or stored near ground level.

7. Wind Direction and Speed. Wind direction and intensity will influence the amount of particulates that impinge on test material. At coastal sites moisture and salt are also transported by wind.

8. Salt Content in Air. Salt content in air will affect the rate of electrolytic corrosion of metals. Sites with high atmospheric salt levels exhibit high corrosion rates.

9. Microbial Activity. Microbial activity is important whenever microorganisms use the exposed sample as a nutrition source and allied metabolic products are detrimental to the material.

10. Insect Fauna. Exposed items, in many instances, serve as food and as a habitat for a variety of insects. Metabolic waste from these insects may damage the exposed items through the action of organic acids or by acting as a substrate for microbial attack.

APPENDIX D

DESCRIPTION OF EXPOSURE SITES

1. U.S. Army Tropic Test Center (USATTC) has exposure sites on the Atlantic and Pacific sides of the Panama Isthmus. A description is given of the severity of several exposure sites for selected materials in the USATTC report, Determination of Optimum Tropic Storage and Exposure Sites.[a] The climate of the USATTC sites is classified as either constant high humidity (B1) or variable high humidity (B2) by AR 70-38. Climatic data for each exposure site can be obtained from: Commander, Atmospheric Sciences Laboratory Meteorological Team (Panama), APO Miami 34004. Additional exposure testing data may be found in USATTC report, Materiel Testing in the Tropics.[b]

2. On the Atlantic side, there are six atmospheric exposure sites. Five are located in Fort Sherman, and one is located at Fort Gulick.

Sites	Grid Coordinates
Fort Sherman Marine Breakwater Exposure	15603614
Fort Sherman Coastal Exposure	15203596
Fort Sherman Open Exposure	14803484
Fort Sherman Forest Exposure	14603113
McKenzie Forest Exposure	11093190
Fort Gulick Munitions Surveillance	25203045

a. The Marine Breakwater Exposure site is located on the west breakwater at the northern entrance of the Panama Canal on Toro Point. The area is barren with sparse vegetation. Wind blows continuously from the north. There is considerable salt spray because of the combined effect of continuous wave action and wind. The site is open with no shade and is 84x45m. It has four pipe stands to accommodate exposure racks.

b. The Coastal Exposure site, 12x20m, is located near the Jungle Operations Training Center, 500m west of the breakwater site. Although it is located on the coast, it is not directly on the beach. The atmospheric salt content is much less than at the breakwater site (although much greater than at inland sites). Vegetation is sparse with no trees for shade.

c. The Open Exposure Site, 60x30m, is about 1.6km inland. The atmospheric salt content is much less than at the coastal or breakwater sites. The site floor is covered by grass, and there is no vegetation to shade the exposure racks.

d. The Forest Exposure Site is located in a tropical moist forest.[c] The forest canopy covers the site completely, and the trees are considered mature. The relative humidity at this site remains fairly constant near 95% during the wet season. Little sunlight reaches the forest floor, and the atmospheric salt content is low. This site should be used for exposure of noncritical materials because it is unguarded and unfenced. AC power is not available.

e. The McKenzie Forest Exposure Site is located in a tropical moist forest.[c] The age of the trees at the site varies from 25 to 100 years, and these trees are considered to be near maturity. The forest canopy is irregular varying from 18 to 35m. Canopy coverage is about 100% at this site, and there is a semidense secondary growth of shrubs, vines, and creepers. Generally, the canopy species are evergreen or semievergreen. The atmospheric salt content at this site is low. The exposure site, 16x9m, is surrounded by a chain-link fence, and AC power is available.

f. The Fort Gulick Munitions Surveillance Site is located in the magazine area of Fort Gulick near Gatun Lake. It is a secured area used to expose ammunition and is surrounded by a double chain-link fence. The site contains a metal-covered, fenced-in storage shed 6.04x9.75m. Most of the vegetation near the site is grassland.

3. On the Pacific side of the isthmus, USATTC has two sites in Fort Clayton and one site at the Rodman Naval Station.

Sites	Grid Coordinates
Fort Clayton General Purpose Test Area	55609850
Fort Clayton POL Tank Farm	58129523
Rodman Naval Station Munitions Surveillance Site	52479160

a. The general purpose test area has a variety of different exposure sites because of its relatively large area. The exposure sites differ from each other, such as under canopy, in the open, on a creek, on a slope, grasslands, and others. This test area is secured and has a guard on duty 24 hours a day. However, because of its relatively large amount of grasslands, precautions against fire must be taken during the dry season. Shelters, cages, and buildings are available.

b. The POL Tank Farm was established primarily to participate in the field failure analysis of collapsible fabric tanks. The site consists of a secured fenced area of 7.1 hectares. Temporary office, storage, and maintenance building space is provided within the secured area. The site is characterized by high solar radiation and low-salt-air exposure. Vegetation ranges from sparse to grass covered. Improved roads reach all structures.

c. The munitions surveillance site is a secured area and is used to expose ammunition and "sensitive" items. USATTC has three cages, two with paved floors and the third graveled. One of the cages has a tin roof. Most of the surface of the site is covered with vegetation including mature forests and grasslands.

APPENDIX E

REFERENCES

Required References

1. MTP 5-2-584, Microbial Resistance Tests, 6 June 1968; Change 1, 2 June 1972.

2. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 1 August 1979.

3. AR 750-25, Army Test, Measurement, and Diagnostic Equipment Calibration and Repair Support Program, 1 September 1983.

References for Information Only

a. Sprouse, J.F.; Neptune, M.D.; and Bryan, J.C., Determination of Optimum Tropic Storage and Exposure Sites, Report II, Empirical Data. Canal Zone, U.S. Army Tropic Test Center, TECOM Project No. 9-CO-009-000-006, AD No. A005017, USATTC Report No. 7403001, March 1974.

b. Materiel Testing in the Tropics, U.S. Army Tropic Test Center, TECOM Project No. 9-CO-150-000-099, USATTC Report No. 790401, April 1979.

c. Holdridge, L.R., et al, Forest Environments in Tropical Life Zone: A Pilot Study. London: Pergamon Press, 1971.