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radar	pitch and roll	interface testing
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terrain tracking	optical or radar tracking	surface pips
altitude simulator	indicated altitude	multipath reflections
frequency variation	terrain profile	reflected pips
sensitivity		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This test operations procedure (TOP) delineates general test and specific subtest procedures required to determine the technical performance of absolute altimeters as specified in Qualitative Materiel Requirements (QMR), Technical Characteristics (TC) and Required Operational Capability. (ROC) (Cont)

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Absolute altimeters are employed to measure vertical separation between the aircraft and the surface of the earth. Absolute altimeters may also be referred to as "Radio" or "Radar" altimeters as they determine absolute terrain clearance by measuring the time interval required for a radio frequency signal to travel from the aircraft to the terrain and back again.

This TOP is limited to tests outlined here-in which are applicable only to absolute altimeters. This TOP makes no attempt to describe tests of pressure or barometric altimeters. Procedures for testing this type of altimeter are contained in 5-2-515(N).

The following tests will determine:

a. Warm-up-Time. The time required for the test item to become operational after activation.

b. Primary Voltage Sensitivity. The effect of varying supply voltages on system performance and to determine the minimum and maximum voltage ranges for which the test item operates satisfactorily. The effect of frequency variation in the AC supply will also be determined.

c. Mutual Interference. If mutual interference exists between the test item and electronic equipment standard to the applicable aircraft. The test includes both a static and dynamic examination.

d. Low Altitude Accuracy and Resolution. The absolute accuracy and resolution capabilities of the test item from 0-50 feet (0-15.24 m) altitude.

e. Failsafe. The features which show a positive indication when the altitude indicator in unreliable.

f. Pitch and Roll. The angle of test item antenna plane at which the test item begins to indicate slant range, "unlock" or failsafe.

g. Accuracy and Range. If the test item will operate satisfactorily throughout its entire indicating range, to determine the accuracy of the altitude information presented to the aviator, and to determine if aircraft speed has any effect on the test item.

h. Terrain Tracking. The ground tracking ability of the test item when measuring altitude over gently rolling terrain and over terrain with rapidly varying contours.

i. Over Water. The effect of a wind-blown water surface on the accuracy of the test item at selected low and high altitudes.

j. Adverse Weather. The effect of adverse weather on the test item.

k. Over Icecaps and Snow. The altimeter's ability to function correctly when operating over an iceacap or deep snow field.

l. Continuous Operation. If the test item will operate continuously and reliably for the period specified in the requirements.

US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105 1 September 1983
Test Operations Procedure 6-2-103*
AD No. A131746

ABSOLUTE ALTIMETERS

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1.0 SCOPE. This test operations procedure (TOP) delineates general test and specific subtest procedures required to determine the technical performance of absolute altimeters as specified in Qualitative Materiel Requirements (QMR), Technical Characteristics (TC), Small Development Requirements (SDR) and Required Operational Capability (ROC) documents as applicable.

a. Absolute altimeters are employed to measure vertical separation between the aircraft and the surface of the earth. Absolute altimeters may also be referred to as "Radio" or "Radar" altimeters as they determine absolute terrain clearance by measuring the time interval required for a radio frequency signal to travel from the aircraft to the terrain and back again. Appendix A, provides additional information concerning the underlying principles of absolute altimeters.

b. There are many factors which affect the operation of the absolute type altimeter. These factors include weather and climatic conditions, aircraft roll and pitch, and terrain reflection characteristics. The effects of terrain reflection characteristics, including typical behavior diagrams of radar altimeters over water, rock, snow and ice are described in Appendix B.

c. This TOP is limited to the tests outlined here-in which are applicable only to absolute altimeters. This TOP makes no attempt to describe tests of pressure or barometric altimeters. Procedures for testing this type of altimeter are contained in TOP 5-2-515(N).

2.0 FACILITIES AND INSTRUMENTATION. The test item shall be placed in operating condition as outlined in the equipment technical manual.

*This TOP supersedes MTP 6-2-013, 6 February 1968.

2.1 Facilities. A grounded bench test facility in a shielded room with power supply and a non-reflective elevation platform equipped with a non-reflective tower. The 114 foot (34.75 m) tower is all wood, above ground level, and held together with phenolic bolts. It is a part of the proving ground's Antenna Pattern Measuring Facility. Other facilities are: Optical or radar tracking facilities, Environmental chamber, a rotary wing aircraft and a suitable aircraft.

2.2 Instrumentation and Equipment. Variable power supply(ies); timer; altitude simulator; aircraft electronic equipment; multichannel recording voltmeter and recording charts video camera/recording equipment and/or motion picture camera and film; precision barometric altimeter and/or a precision reference distance measuring laser; and weather measuring instrumentation.

Characteristics/Requirements. The above listed major facilities, instrumentation and equipment will provide the necessary characteristics and setups required to perform the following subtest procedures which will determine:

a. Warm-up-Time. The time required for the test item to become operational after activation.

b. Primary Voltage Sensitivity. The effect of varying supply voltages on system performance and to determine the minimum and maximum voltage ranges for which the test item operates satisfactorily. The effect of frequency variation in the AC supply will also be determined.

c. Mutual Interference. If mutual interference exists between the test item and electronic equipment standard to the applicable aircraft. The test includes both a static and dynamic examination.

d. Low Altitude Accuracy and Resolution. The absolute accuracy and resolution capabilities of the test item from 0 to 50 feet (15.24 m) altitude.

e. Failsafe. The features which show a positive indication when the altitude indicator is unreliable.

f. Pitch and Roll. The angle of test item antenna plane at which the test item begins to indicate slant range, "unlock" or failsafe.

g. Accuracy and Range. If the test item will operate satisfactorily throughout its entire indicating range, to determine the accuracy of the altitude information presented to the aviator, and to determine if aircraft speed has any effect on the test item.

h. Terrain Tracking. The ground tracking ability of the test item when measuring altitude over gently rolling terrain and over terrain with rapidly varying contours.

i. Over Water. The effect of a wind-blown water surface on the accuracy of the test item at selected low and high altitudes.

j. Adverse Weather. The effect of adverse weather on the test item.

k. Over Icecaps and Snow. The altimeter's ability to function correctly when operating over an icecap or deep snow field.

l. Continuous Operation. If the test item will operate continuously and reliably for the period specified in the requirements.

3.0 PREPARATION FOR TEST

a. The test procedures outlined herein shall be subjected to repetition to simulate an equivalent number of units tested one time each.

b. Consult TOP 3-1-002, Confidence Intervals and Sample Size prior to testing in order to ensure statistical validity of the resultant data.

c. All instrumentation errors and their associated standard deviations shall be investigated and cataloged prior to testing.

d. Data to be recorded prior to testing shall include but not be limited to:

(1) Nomenclature of the test item

(2) Serial number of the test item

(3) Manufacturer of the test item

(4) Identification of the aircraft in which the test item is mounted

(5) Appropriate photographs of the test item

e. The following data shall be required in addition to specific instructions listed for each individual subtest:

(1) An engineering log book containing in chronological order pertinent remarks and observations which would aid in a subsequent analysis of the test data.

(2) Instrumentation or measurement system mean error and standard deviation of error

(3) Test item sample size (number of measurement repetitions).

4.0 TEST CONTROLS

a. Select test equipment having an accuracy of at least 10 times greater than that of the function to be measured.

b. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in the QMR, SDR, TC, and ROC documents.

c. Review all instruction material issued with the test item by the manufacturer, contractor, or Government, as well as reports of previous tests conducted on the same types of equipment, and familiarize all test personnel with the contents of such documents. These documents shall be kept readily available for reference.

d. Inspect the test item thoroughly for obvious physical and electrical defects such as cracked or broken parts, loose connections, bare or broken wire, loose assemblies, bent relay and switch springs, and corroded plugs and jacks. All defects shall be noted and corrected before proceeding with the tests.

e. Prepare record forms for systematic entry of data, chronology of tests, and analysis in final evaluation of the test item.

f. Prepare adequate safety precautions to provide safety for personnel and equipment, and ensure that all safety SOPs are observed throughout the test.

5.0 PERFORMANCE TESTS

NOTE: Modifications of these procedures shall be made as required by technical design of the test item and availability of test equipment, but only to the extent that such modified procedures will not affect the validity of the test results. Reference Figure 1.

NOTE: The altitude simulator consists of a plane reflector and appropriate instrumentation to electronically or mechanically orient the altimeter's antenna.

5.1 Warm-up Time

This test shall only be performed on altimeters which require a finite time interval to operate satisfactorily after the primary power has been applied.

a. Mount the test item in an environmental chamber.

b. Connect the altimeter to the altitude simulator instrument.

c. Supply primary power to the altimeter in accordance with military specifications.

d. After sufficient warm-up time, adjust the altitude simulator instrument to achieve a convenient mid-scale altitude reading.

e. Remove the primary power from the test item.

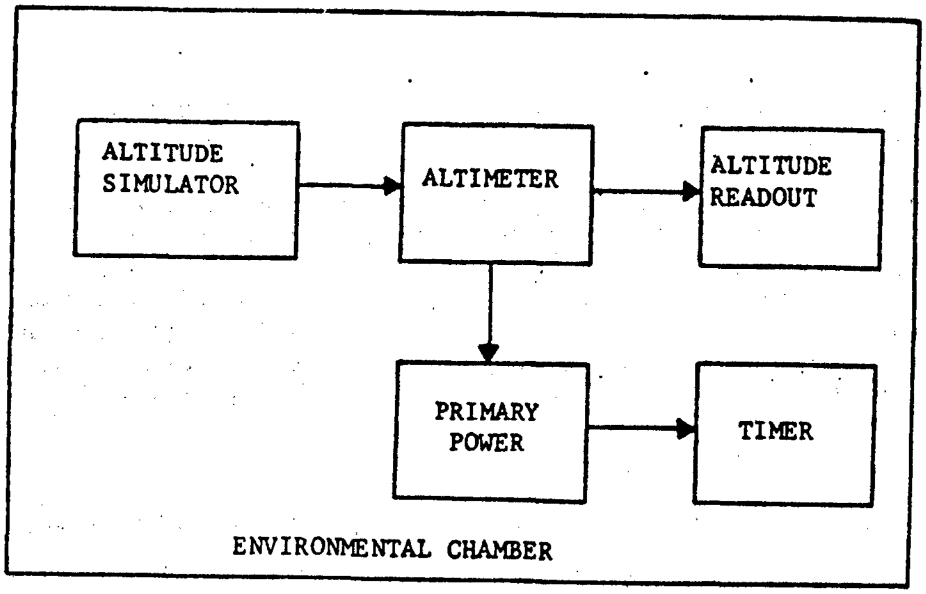

Figure 1. Test Setup

f. Adjust the environmental temperature to the lower extreme of -51°C (-60°F).

g. Record environmental temperature in degrees fahrenheit.

h. Apply the primary power and start timer after the test item is stabilized at the environmental temperature, -51°C (-60°F).

i. Observe and record the time required for test item to return to the mid-scale altitude reading as determined in step d, and the temperature.

j. Repeat steps e through i, five times.

k. Repeat steps e through j, for 10 different environmental temperatures up to the extreme high of 55° C(131°F).

5.2 Primary Voltage Sensitivity

5.2.1 Preparation

a. Prior to testing, the test item shall be categorized with respect to usage in accordance with MIL-STD-704 and all power and frequency limits outlined therein shall be strictly adhered to during testing in order to prevent damage to test item's circuitry.

b. The following tests shall be performed on the test item by varying a DC or AC, power supply while maintaining any other primary power supplies at their specified nominal value.

c. Connect test item to the variable power supply.

d. Connect the altimeter to the altitude simulator.

5.2.2 Power Supply Sensitivity

a. Adjust the altitude simulator to achieve a convenient mid-scale altitude reading

b. Adjust the DC or AC power supply to the minimum energency voltage value given, in MIL-STD-704, and record the altimeter reading

c. Increase the power supply voltage in 10 steps up to the maximum emergency voltage value given in MIL-STD-704, and record the altimeter reading and voltage at each step. In each case, allow the altimeter sufficient time for transients to settle before recording the indicated altitude.

5.2.3 Frequency Variation Sensitivity

The sensitivity of the test item to variations in the AC power supply shall be determined by the following procedures:

a. Adjust the altitude simulator to achieve a convenient mid-scale altitude reading

b. Adjust the frequency of the AC power supply to 360 Hz (minimum emergency frequency) and record altimeter reading and frequency

c. Increase the frequency of the AC power supply in eight steps up to 440 Hz (maximum emergency frequency) and record the indicated altitude reading and corresponding frequency at each step. In each case allow the altimeter sufficient time for transients to settle before recording the indicated altitude.

5.3 Mutual Interference

5.3.1 Static Test

The static mutual interference test is a laboratory test to determine the frequency, source, and field strength of radiations emanating from the test item's case, connecting cables or power cord.

a. Preparation

(1) Mount the altimeter on a grounded metal bench top in a shielded room and terminate the antenna to appropriate instrumentation.

(2) The altimeter shall function in it's normal operating mode.

(3) Set the noise and field intensity meter (NFIM) to its most sensitive range.

b. Test Conduct

(1) Place the NFIM antenna probe near the test item case, and tune the NFIM until an indication is obtained.

(2) Calibrate the NFIM as a two terminal vacuum tube voltmeter.

(3) Move the antenna probe until a point or general area is found on the test item at which the radiation is maximum.

(4) Record the following:

(a) Frequency at which NFIM is set (emission frequency (Hz))

(b) Level as measured by the NFIM in decibels above one microvolt (emission amplitude) (db/ v/m)

(c) RMS value of level measured

(d) Location of maximum leakage

(e) Emission origin (i.e., 2nd harmonic of local oscillator)

(5) Repeat steps, 1 through 4, to measure all detectable leakage in the range of 10 kHz to 1000 MHz

5.3.2 Dynamic Test

a. Connect the altimeter in the aircraft test configuration.

b. Individually activate each of the aircraft's electronic equipment (including the test item) and adjust its controls such that a standard response is indicated similar to that which will be observed in normal operation.

c. Observe and record the standard response achieved for each indicator.

d. Activate, in turn, each of the aircraft's electronic equipment in conjunction with the test item.

NOTE: If any changes in standard response levels are observed, interference is said to exist and further investigation shall be made, where possible to determine the precise nature of the interference.

e. Record the following data whenever any interference is observed:

(1) Nomenclature of equipment interferred with

(2) Standard response level after interference

f. Simultaneously activate all of the aircraft's electronic equipment (including test item)

g. Observe standard response levels achieved

h. Where interference is seen to exist by changes in the standard response levels, briefly deactivate in turn individual equipment and record the following data:

(1) Nomenclature of interfering equipment

(2) The effect of removing that particular equipment from service with respect to the response levels.

5.4 Low Altitude Accuracy and Resolution

a. Preparation

(1) Mount the test item on a non-reflective elevating platform over the reflecting plane.

(2) If continuous operation is selected, then accurate timing and altitude information shall be recorded on all data to permit post test correlation.

(3) The test item shall function in its normal low altitude mode of operation.

b. Test Conduct

(1) Hoist the test item to 50 feet (15.24 m) in increments of 1 foot.

(2) At each increment record the test item's indicated and absolute altitudes

(3) Lower the test item in 1-foot increments from 50 feet (15.24 m) and repeat step 2.

(4) Repeat steps 1, 2, and 3, a sufficient number of times in order permit statistical analysis of a recorded data.

5.5 Failsafe

5.5.1 Instrument Failure

a. Simulate instrument failures by any of the following possible means:

(1) Remove a critical component of the test item.

(2) Remove the primary supply voltage from the test item.

(3) Disconnect transmission cables or mechanical links from between components of the test item.

b. Observe and record failsafe indications and altimeter readings when subjected to the above simulated failures.

c. Simulate a sufficient variety of equipment failures to allow for an adequate analysis of failsafe operation.

5.5.2 Exceeding Instrument Capabilities

Throughout the test procedure and especially in conjunction with the pitch and roll subtest, conditions will be encountered in which the test item is forced to exceed its design limits. This subtest, therefore, shall consist of recording the time, type, cause and circumstances of each failsafe indication.

5.6 Pitch and Roll

The test shall be conducted under static conditions for altitudes up to 50 feet and as a dynamic test for altitudes from 50 through 2000 feet (15.24 through 609.6 m).

5.6.1 Static Test

a. Preparation

(1) Mount the test item on a non-reflective tower or catenary system which will allow pitch freedom of ±90°, from horizontal (where positive pitch is up) and roll freedom of ±90° from vertical (where roll right is positive).

b. Test Conduct

(1) Orient the elevatable platform at an altitude of 10 feet (3.05 m) in horizontal reference position (test item antenna beam vertically downward) and record the indicated altitude and true altitude.

(2) For the following conditions, determine and record the angle at which the test item begins to indicate slant range (and "unlock" or failsafe where applicable) as the test item is rotated away from the reference position and return of reliable altitude indication as test item is rotated back to the reference position.

(a) Pitch up and return to reference

(b) Pitch down and return to reference

(c) Roll right and return to reference

(d) Roll left and return to reference

(3) Raise the platform in 10-foot (3.05 m) increments to 50 feet (15.24 m) recording indicated and true altitude and repeating step 2 at each altitude.

(4) Repeat steps 1 through 3 five times in order to be able to compute averages of five readings at each of five altitudes.

(5) Record all failsafe indications for inclusion in subtest 5.5.2.

5.6.2 Dynamic Test

a. Preparation

(1) Mount the test item in a suitable aircraft.

(2) Aircraft tracking facilities or precision barometric instrumentation shall be available to ascertain the precise altitude of the aircraft during the test.

b. Test Conduct

(1) For absolute altitudes of 100, 500, 1000 and 2000 feet (30.48, 152.4, 304.8, and 609.6 m) over relatively flat terrain, alternately pitch up and down, then roll right and left to the safety limits of the aircraft or until the test item capabilities are exceeded.

(2) Observe and record the angle at which loss of ground track (and "unlock" or failsafe where applicable) occurs.

(3) Observe and record the angle at which the test item returns to proper operation as the aircraft returns to straight and level flight.

(4) Record all failsafe indications for inclusion in subtest 5.5.2.

5.7 Accuracy and Range

5.7.1 Preparation

a. Choose a level strip of land.

b. Employ an optical or radar tracking system with the capability of determining the space position of the test vehicle, including absolute altitude to at least the accuracy specified for the altimeter under test and to independently determine aircraft altitude located adjacent to the strip of land.

c. Provide a means such as motion picture photography to record aircraft indicated altitude.

d. Accomplish positive time synchronization on all data to permit correlation.

e. Mount the test item mounted in a rotary-wing aircraft.

NOTE: This will allow continuous data to be collected because of near vertical type of flight possible.

f. Connect the altimeter to a multi-channel recording voltmeter to record analog voltage of altitude.

5.7.2 Discrete Altitude Test Conduct

a. Fly the aircraft to the test strip and obtain an altitude of 50 feet (15.24 m) above the strip.

b. Signal the beginning of the data run to all data collectors when the aircraft is properly situated and flying at a velocity as specified in specific operational and technical requirements for the altimeter under test.

c. Record the following data at all stations for 10 seconds:

(1) Precise, independent reference reading of altitude as provided by optical or radar tracking system, or precision barometric instrumentation.

(2) Analog voltage of altitude.

(3) Indicated altitude.

d. Climb to 100, 200, and 500 feet (30.48, 60.96, and 152.4 m) sequentially, repeating steps b and c, at each altitude.

e. Switch to high scale (where possible) and repeat steps b and c, for 500 feet and each succeeding 500 feet (152.4 m) increment up to the altitude limit of the test item or the aircraft ceiling.

f. Perform steps d through e, in reverse order descending from the altitude limit of test item or aircraft ceiling to an altitude of 50 feet (15.24 m).

g. Repeat steps b through f, for increased aircraft speeds as specified in specific operational and technical requirements for the altimeter under test.

h. Observe and record any failsafe indications for inclusion in subtest 5.5.2.

5.7.3 Continuous Altitude Test

a. Fly the aircraft to the test strip and climb until maximum altitude capability of test item is exceeded.

b. Situate the aircraft properly and have it begin descending at its maximum rate consistent with safety while introducing minimum pitch and roll.

c. Record the following data at all stations:

(1) Precise barometric reading of altitude

(2) Analog voltage of altitude

(3) Indicated altitude

d. Stop descent and cease data recording at an altitude of 50 feet (15.24 m).

e. Observe and record any failsafe indications for inclusion in subtest 5.5.2.

5.7.3.1 High Range Altimeters

Employ an altitude simulator for altimeters with maximum range greater than the ceiling of the rotary wing aircraft for additional testing.

a. Connect the test item in the laboratory to an altitude simulator.

b. Raise the simulated altitude in excess of the maximum altitude capability.

c. Simulate decreasing altitude approximately the descent used in step b, of paragraph 5.7.3, and begin recording the following data with timing:

(1) Precise barometric reading of altitude

(2) Analog voltage of altitude

(3) Indicated altitude

d. Stop recording when an altitude corresponding to aircraft ceiling is reached.

e. Observe and record failsafe indications for inclusion in subtest 5.5.2.

5.8 Terrain Tracking

a. Preparation

(1) Choose a test area which has a rapidly changing contour which can be overflown in approximately two or three minutes and is adjacent to the tracking system.

(2) Make available accurate contour maps of the test area.

(3) Employ an optical or radar tracking system to determine accurate aircraft space position.

(4) Make the minimum elevation angle from any one radar greater than 5° if radar tracking is employed, in order that elevation "wander" (multipath reflections) does not affect the position data.

NOTE: In the final analysis, however, the accuracy of the contour map will probably limit overall measurement accuracy.

(5) Provide a means such as motion picture photography to record aircraft indicated altitude.

(6) Connect a multi-channel voltage recorder to the altimeter.

(7) Achieve positive time synchronization on all data to permit post test correlation.

(8) Mount altimeter and install data recording equipment in a suitable aircraft.

b. Test Conduct

(1) Fly aircraft in a staight and level course over the test area at a constant velocity.

(2) Signal the aircraft's start and end of data run.

(3) Record the following at all stations during run:

(a) Aircraft space position

(b) Indicated altitude

(c) Analog voltage

(d) Terrain profile

5.9 Over Water

a. Preparation

(1) Choose a test range located near a body of water and equipped with the optical or radar tracking facilities.

(2) Provide a means such as photography for continuously recording the test items display indications.

(3) Provide a means for monitoring weather conditions.

(4) Achieve positive time synchronization on all data to permit correlation.

(5) Mount the altimeter in the aircraft to be used for the test.

b. Test Conduct

(1) Direct the aircraft containing the test item, assuming suitable weather conditions at the test site, to maintain a pressure altitude of 100 feet (30.48 m) (or lowest altitude consistent with aircraft safety).

(2) Observe and record meteorological conditions and sea state.

NOTE: Ideal weather conditions would be clear with steadily blowing winds.

(3) Record the following data with the aircraft flying straight and level over the body of water, at all stations for 20 seconds with aircraft first oriented parallel; then perndicular to the wind vector.

(a) Test item indicated altitude

(b) Aircraft space position information

(4) Repeat steps 1 through 3, for pressure altitudes of 200, 500, 1000 and 2000 feet (60.96, 152.4, 304.8, and 609.6 m).

(5) Repeat steps 1 through 4, for a sufficient number of wind velocities in the 10-50 knot (18.52-92.6 km/hr) range in order to be able to plot a family of curves.

5.10 Adverse Weather

a. Preparation

(1) Provide a means to simultaneously record pressure and absolute altitude indications, for example, by motion picture photography.

(2) Mount the test item in a suitable aircraft.

(3) Choose a test range equipped with the optical or radar tracking facilities.

(4) Achieve positive time synchronization on all data to permit correlation.

(5) Provide a means of monitoring weather conditions.

b. Test Conduct

(1) Check for the effect on the test item of the following adverse weather conditions:

(a) Clouds

(b) Rain

(c) Snow

(d) Hail

(e) Dust storms

(f) Lightning

NOTE: Different intensities of these phenomena will be required to provide data for quantitative assessment of the effect.

(2) Instruct the pilot to fly near, over, and through the phenomenon of interest to the degree that safety permits.

(3) Record simultaneously when the test item is affected both the absolute and pressure altitude indication.

(4) Record a normal indication in the immediate vicinity when possible.

(5) Advise operators when to record data if ground tracking is available.

(6) Record data for verification of normal operation where no effect is evident.

(7) Obtain quantitive data on the phenomenon monitored whenever possible.

5.11 Over Ice and Snow

a. Preparation

(1) Provide a means, such as photography for continuously recording the test items display indications.

(2) Choose an appropriate test area equipped with the optical or radar tracking with the capability of determining space position of the test vehicle, including absolute altitude, to at least the accuracy specified for the altimeter under test.

(3) Achieve positive time synchronization on all data to permit correlation.

(4) Prepare accurate maps of the ice, snow, and ground surface elevations beneath aircraft test course.

(5) Mount the test item in a suitable aircraft to be used for the test.

(6) Connect the altimeter to the multi-channel recording voltmeter.

b. Test Conduct

(1) Direct aircraft containing test item to fly a predetermined path over the test area at an altitude commensurate with aircraft safety and test item resolution

(2) Record continuously the following data in order to be able to plot a family of curves:

(a) Test item indicated

(b) Analog voltage

5.12 Interface Testing

Repeat steps 1 and 2, of paragraph 6.2.11 to include flight over ice/water, snow/ice, and ice/earth interfaces.

5.12.1 Static Test

Substitute under some conditions, a static test for the dynamic test in paragraph 5.8 through 5.12 for altimeters of low resolution capabilities (several feet).

a. Preparation

(1) Mount the altimeter on a nonreflective elevatable platform at a known distance above the surface.

(2) Connect a multi-channel recording voltmeter to the altimeter.

b. Test conduct

(1) Take measurements at several altitude and locations over the test area.

(2) Record the following data at each location:

(a) Indicated altitude

(b) Known altitude

(c) Analog voltage

(d) Interface

5.13 Continuous Operation

a. Preparation

(1) Connect the test item in the laboratory to an altitude simulator.

(2) Connect a multi-channel recording voltmeter to record the following voltages:

(a) Automatic frequency control (AFC) voltages

(b) Automatic gain control (AGC) voltages

(c) Test item generated high voltage(s)

(d) Laboratory primary power supply(ies)

b. Test Conduct

(1) Adjust the altitude simulator such that a valid altitude is registered on the low scale of the altimeter.

(2) Record the monitored voltages for 15 minutes. During this interval operate the scale switch (where applicable) and verify return to normal operation.

(3) Repeat step 1 and 2, every hour during the period specified in the requirements.

6.0 DATA REQUIRED

6.1 Preparation

a. Record the following data recorded prior to testing:

(1) Nomenclature of test item

(2) Serial number of the test item

(3) Manufacturer of test item

(4) Identification of the aircraft in which the test item is mounted

(5) Appropriate photographs of test item

b. Take the following required data in addition to specific instructions listed for each individual subtest:

(1) An engineering log book containing in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of test data.

(2) Instrumentation or measurement system mean error and standard deviation of error.

(3) Test item sample size (number of measurement repetitions).

6.2 Test Conduct

6.2.1 Warm-up Time

a. Record the environmental temperature in degrees Fahrenheit.

Record the warm-up time in seconds for each of five measurements taken at each temperature level.

6.2.2 Primary Voltage Sensitivity

a. Power supply sensitivity - Record all indicated altitude readings and corresponding power supply voltage settings.

b. Frequency variation sensitivity - Record indicated altitude readings and corresponding values of AC power supply frequency.

6.2.3 Mutual Interference

a. Static Test

(1) Emission frequency (Hz)

(2) Emission amplitude (db/ v/m)

(3) RMS value of amplitude

(4) Emission origin (e.e., secnd harmonic of local oscillator)

(5) Location of maximum leakage

b. Dynamic Test - Record the following data:

(1) Nomenclature of equipment interfered with

(2) Nomenclature of interfering equipment

(3) Standard response level before interference

(4) Standard response level after interference

6.2.4 Low Altitude Accuracy and Resolution

Record indicated and absolute altitudes

6.2.5 Failsafe

a. Instrument Failure - Observe and record failsafe indications, altimeter readings, type and nature of simulated failure readings.

b. Exceeding instrument capabilities - Record time, type, cause and circumstances of all failsafe indications observed during testing.

6.2.6 Pitch and Roll

Record the following data during pitch and roll test.

a. True altitude

b. Indicated altitude

c. Angle at which indicator deviates from true altitude for each condition of pitch and roll.

d. Angle at which the indicator returns to true altitude for each condition of pitch and roll.

6.2.7 Accuracy and Range

Record the following data:

a. Absolute altitude

b. Indicated altitude

c. Analog voltage of altitude

6.2.8 Terrain Tracking

Record the following data:

a. Test item indicated altitude

b. Aircraft space position information

c. Test item analog voltage

d. Terrain profile

6.2.9 Over Water

Record the following data:

a. Meteorological conditions and sea state

b. Test item indicated altitude

c. Aircraft space position information

6.2.10 Adverse Weather

Record the following data:

a. Meteorological conditions

b. Test item indicated altitude

c. Absolute altitude

6.2.11 Over Ice and Snow

Record the following data for ice and snow tests:

a. Test item indicated altitude

b. Aircraft space position information

c. Interface and surface profile

6.2.12 Interface Testing

Record data as specified in paragraph 6.2.11.

6.2.13 Continuous Operation

Record the the following voltages:

a. Automatic frequency control (AFC) voltage

b. Automatic gain control (AGC) voltage

c. Test item generated high voltage(s)

d. Laboratory primary power supply(ies)

7.0 DATA REDUCTION AND PRESENTATION

Processing of raw test data shall consist of computing mean values and standard deviations of measurements and measurement errors, and organizing data into tabular and graphical form. All test data shall be properly marked for identification and correlation and grouped according to subtest title.

A written report shall accompany the tabular test data and shall emphasize test results and present conclusions and recommendations drawn from analysis of the test findings. Specific instructions for the reduction and presentation of individual subtest data are outlined in the succeeding paragraphs.

7.1 Warm-up Time

Reduce warm-up test data to a tabular listing of environmental temperature as the independent variable and mean warm-up time as the dependent variable.

7.2 Primary Voltage Sensitivity

Present primary voltage sensitivity data graphically as curves of:

a. DC power supply voltage versus indicated altitude

b. AC power supply voltage versus indicated altitude

c. AC power supply frequency versus indicated altitude

7.3 Mutual Interference

Present mutual interference data present in tabular form as outlined in paragraph 6.2.3.

7.4 Low Altitude Accuracy and Resolution

Reduce low altitude accuracy and resolution data to mean error and standard deviation of error and presented graphically. Show Data points on the graphical presentation for each one foot interval on the abscissa.

7.5 Failsafe

Present failsafe data as outlined in paragraph 5.5, emphasis shall be placed on defining the operational limits of the test item with respect to failsafe indications.

7.6 Pitch and Roll

Pitch and roll data collected in accordance with paragraph 5.6 shall be reduced to mean values of pitch and roll angle and graphical presentation made of mean pitch and roll angles versus true altitude.

7.7 Accuracy and Range

Reduce accuracy and range data to mean error and standard deviation of error and present them graphically.

7.8 Terrain Tracking

Present terrain tracking data graphically.

7.9 Over Water

Reduce over water test data to mean error and standard deviation of error and present them in a graphical manner. Compute the Beaufort index of sea state and separate error and standard deviation graphs presented for each Beaufort number encountered in testing. Present additional meteorological phenomenon encountered which may have influenced test item behavior and their effects noted.

7.10 Adverse Weather

Reduce adverse weather test data to mean error and standard deviation of error for each type of adverse weather encountered and present them in tabular form.

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7.11 Over Icecaps and Snow

Compile over icecaps and snow data and present it graphically. Note operation of the test item over the ice/water interface and present it in a like manner, where possible.

7.12 Interface Testing

Make data reduction similar to that described in paragraph 7.11.

7.13 Continuous Operation

Present continuous operational data collected in conjunction with paragraph 5.11 in tabular form with strip charts from recording devices presented where applicable.

APPENDIX A
ALTIMETERS

The general category of absolute altimeters may be subdivided into two classifications depending upon the type of modulation employed. The two classifications and their respective operational rationales are as follows:

A. Frequency Modulated Radio Altimeters

The basic principle underlying the operation of an FM radio altimeter is explained in Figure A-1 which gives a curve of frequency against time. The thick line represents the signal sent out by a transmitter whose frequency varies linearly with time and the dotted line represents the same signal, appearing at the receiver at some period of time later. In this particular application the period of time is defined by the time taken for the signal to travel from the aircraft to the ground and back again. Now, if these two signals are mixed in a receiver, the instantaneous transmitter frequency will be higher than the instantaneous received signal and a diference frequency will be detected whose value is proportional to the interval of time t and also proportional to the height. Moreover, it is evident that this difference frequency is a function of the rate of change of carrier frequency and is independent of the carrier frequency itself. Hence the formula:

$$\text{Signal Frequency: } f = F_2 - F_1$$

$$= t \times F$$

Where: $t = \frac{2H}{c}$ or $H = \frac{tc}{2}$

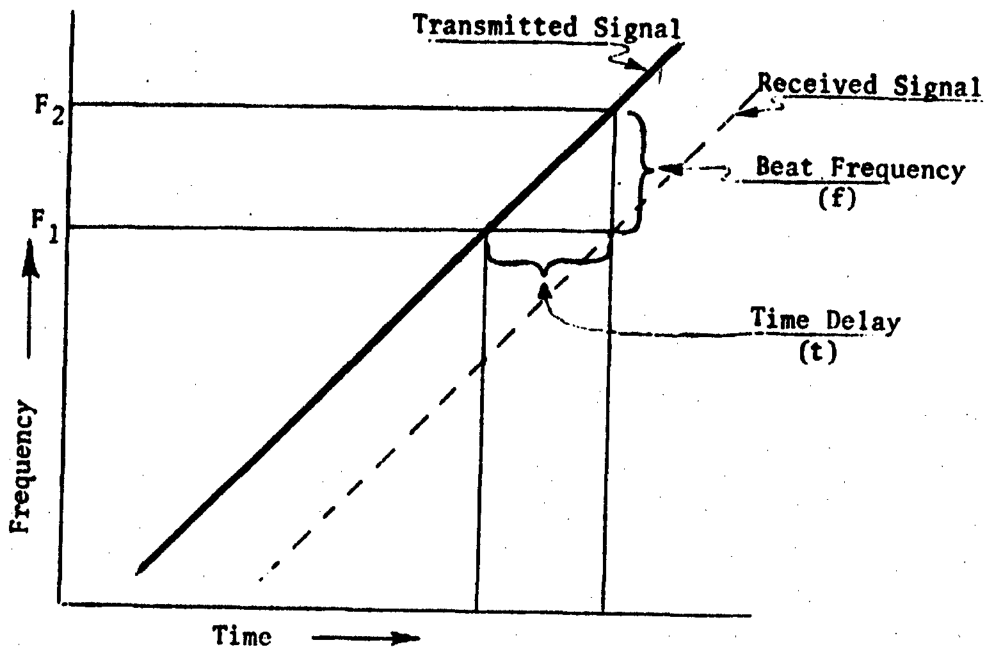
c = Propagation constant
H = Altitude

The signal frequency (f) is electrically converted in the altimeter to solve the above formula in terms of H (altitude) for display on an aircraft type meter.

B. Pulse Modulated Radio Altimeters

The basic principle underlying the operation of pulse modulation altimeters as opposed to frequency modulated altimeters is that pulse modulated altimeters employ the more usual radar principle of measuring the time delay of an echo pulse from the reflected surface. Since electromagnetic energy travels with a propagation velocity c, the altitude H is once again:

$$H = \frac{tc}{2}$$



$$f = (F_2 - F_1) \text{ or } f = t\dot{F}$$

Figure A-1. Frequency versus Time Representation of an FM Radio Altimeter Signal.

The time interval between pulses (t) is electrically converted in the altimeter to display altitude (H) on the aircraft indicator unit.

APPENDIX B

EFFECTS OF TERRAIN REFLECTION CHARACTERISTICS

Rugged Terrain

Terrain Tracking over rugged terrain presents the absolute altimeter with problems of multipath reflection, rapidly varying signal return level, and servomechanism response time limitations. Servomechanism response effects can be isolated from overall altimeter limitations by simultaneously monitoring the analog voltage of altitude (servo input signal) and the altimeter indicator.

Over Water

Water surfaces are good reflectors of high frequency electromagnetic energy. Undisturbed surfaces act as a plane reflector and present no problem t absolute altimeter accuracy. As the surface becomes irregular such as when wind blown, inpingent energy encounters scattering effects which tend to obscure absoute altimeter readings. At high altitudes, this effect is not too significant and may be even less in magnitude than the accuracy of the test item. At low altitudes the scattering effects become significant and will noticeably affect altimeter accuracy. Similar effects may be noted over dense jungle growth.

Adverse Weather

The absolute altimeter is sensitive to weather conditions in varying degrees. Water droplets scatter electromagnetic radiation and thus attenuate the transmitted and received energy. If the density of droplets is high enough (for example, heavy rain), sufficient energy may be reflected from the droplets to induce erroneous altitude sensing. Dust particles, on the other hand, will generally provide only attenuation, except perhaps at very high frequencies. However, the effect of dust particles on the test item will be checked.

Weather checking will be difficult to do on a strictly quantitative basis. This is due to the problem of determining the aircraft altitude from an independent source such as radar or optical tracking. One problem will be locating the desired weather phenomenon near to a tracking system. If this problem can be overcome, the very occurrence to which the test item is to be subjected, such as heavy rain, may obscure the aircraft from the tracking system. Because of these problems, it will sometimes be necessary to use pressure altitude indications as a reference.

Over Ice and Snow

A radar altimeter may be subject to large errors when operating over an icecap or deep snow fields. This error results primarily from the varying opaqueness of thick masses of ice and snow to high frequency radio waves and may be of such a magnitude as to constitute a serious safety hazard to the operation of military aircraft. Additionally, it is noted that a radar altimeter may suffer a loss of signal return over an ice/water interference owing to absorption of the signal in the partially melted boundary area between the ice and the water.

Graphic Simulation

In order to illustrate the discussion of typical behavior of radar altimeters over rock, snow, water and ice, Figure B-2, presents a graphic simulation. Circles at the bottom of each aircraft silhouette shown hypothetical radar altimeter signal pip positions for the diffferent sets of conditions above them.

Position one (Figure B-2) shows the aircraft flying at an elevation of 1620 (493.776 m) feet with both barometric and radar altimeters registering exactly.

Position two shows that the aircraft has moved over 100 (30.48) feet of rock which has only slightly more than half the reflective capabilities of seawater, but still gives a strong return so that the radar altimeter reads 1520 (463.296 m) feet accurately.

The conditions shown in position three illustrate a simple, but common set of over-ice conditions. The aircraft, still 1620 (493.776 m) feet above sea level, is now over 500 (152.4 m) feet of ice and 420 (128.02 m) feet of rock. The radar altimeter shows two reflected pips. The surface pip, still well clear of the zero pip, appears slightly "mushy" as ice doesn't reflect as "sharply" as rock. The bottom pip is weak since the signal received back from the ice/rock interface has undergone attenuation but still produces a recognizable (though somewhat broadened) pip. The altitude indicated by the bottom pip is greater than the altitude from sea level to the fact that it takes almost twice as long for the signal to pass through the ice as it does through the same distance in air. The 500 (152.4 m) foot thick ice thus looks like 930 (283.464 m) feet and since the aircraft is 700 feet (243.84 m) feet above it, the height indicated will be the sum of these or 1630 (496.824 m) as shown.

Position four ignores the signal reflected from the snow shown 20 (6.096 m) feet beneath the aircraft, as well as that from the snow/ice interface 100 (30.48 m) feet below the snow surface because both of the pips caused by these signals will disappear in the zero pip. The only visible pip in this example will be from the rock beneath the 900 (274.32 m) feet of snow and ice and this will have continued to appear higher than the altitude from sea level all the way from position three. Thus, had the pilot even briefly looked away from the indicator as the hillside approached, he might have missed the disappearance of the "surface" pip and have seen only the bottom one when he looked back again. The safe reading on the altimeter thus would cause the pilot to relax just as his aircraft was about to crash.

As indicated above, and in Appendix A, the time required for the passage of radio wave through any medium is determined by the propagation constant (c) of the medium. The propagation constant c for free space is given as 3 x 10^8 meters/sec or 984 x 10^6 feet/sec. Propagation constants for other mediums likely to be encountered by radio altimeters may be calculated from the following formula:

$$c = \frac{1}{\sqrt{\mu \epsilon}} = 2.998 \times 10^8 \text{ m/s}$$

Where: μ = permeability constant = $4\pi \times 10^{-7}$

= 1.257×10^{-6} henry/meter

ϵ = medium permittivity

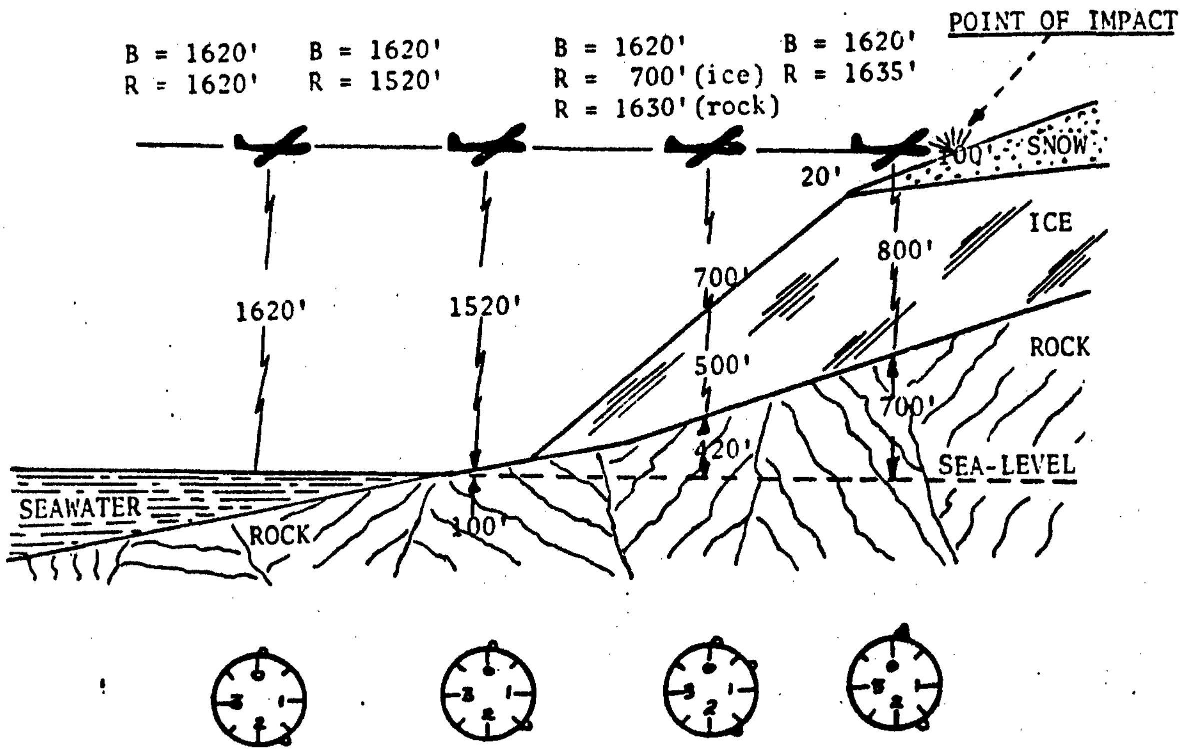
= 8.85×10^{-12} farad/meter for free space

Permittivity values for other mediums (relative to the free space permittivity value) are:

Medium	Relative Permittivity
Air	1
Snow	1.56
Ice	3.5
Rock (low loss)	5.0
Rock (high loss)	10.0

Non-reflective Tower

The tower is 114 feet (34.7472 m) high all wood (completely non-metallic above ground level), self-supporting, square cross-sectioned, and pyramidal in shape. It is used for testing electronic equipment or antennas from 0 to 100 feet (30.4 m) above the ground. A stairway connects platforms at heights of 25, 50, 75, and 100 feet (7.62, 15.24, 22.86, and 30.48 m). The tower is equipped with a cargo elevator and three service elevators. It is held together with phenolic bolts to make it completely non-metallic.



KEY:

B - Barometric Altimeter Reading (Feet)
R - Radar Altimeter Reading (Feet)

1635 ft (498.348 m)	700 ft (243.84 m)
1630 ft (496.824 m)	500 ft (152.4 m)
1620 ft (493.776 m)	420 ft (128.02 m)
1520 ft (463.296 m)	100 ft (30.48 m)
800 ft (243.84 m)	20 ft (6.096 m)

Figure B-2. Typical Behavior of Barometric and Altimeters over Arctic Type Terrain.

APPENDIX C

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