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

This TOP establishes procedures and provides guidance for the testing of an aircraft heading reference system. The primary objective of this document is to determine if the heading reference system under test performs its intended function, within the aircraft environment, with an accuracy and reliability as determined through the appropriate requirements document.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105
*Test Operations Procedure 6-3-120 — 23 June 1982
AD No.

FLIGHT TESTING AIRCRAFT HEADING REFERENCE SYSTEM

1. SCOPE. This TOP establishes procedures and provides guidance for the testing of an aircraft heading reference system (HRS). For the purpose of this TOP, testing implies the test item is properly installed and calibrated into the designated aircraft and evaluated under controlled conditions representing typical aircraft missions. The primary objectives of the test are: (1) To determine if heading reference equipment under test performs its intended function in accordance with the requirements presented in the applicable approved documents,

*This TOP supersedes MTP 6-3-120, Heading Reference Systems, 22 July 1970.

Letter Requirements (LR), Letter of Agreement (LOA), Required Operational Capability (ROC), Materiel Needs (MN), etc., as reflected in the Independent Evaluation Plan/Test Design Plan (IEP/TDP), test directive and/or test request; (2) To evaluate the human factors engineering (HFE) functional characteristics; (3) To evaluate the installation and operational compatibility of the aircraft interface, subsystems, and other instrumentation and equipment; (4) To evaluate the reliability, availability, maintainability (RAM), and logistics supportability of the test system; (5) To evaluate the total overall value engineering aspect of the system; and (6) To identify and evaluate safety and health hazards associated with the operation, installation and maintenance of heading reference system; (7) To determine the electromagnetic compatibility and vulnerability of the subject* system with its intended environment. Environmental testing, MIL-STD 810-C[1], and bench test to include maintenance verification are assumed to have already been accomplished in accordance with TOP 6-2-120.[2]

2. FACILITIES, EQUIPMENT, INSTRUMENTATION, AND SUPPORT REQUIREMENTS. Functional developmental testing of aircraft heading reference equipment will be accomplished within the operational environment of the designated aircraft in accordance with standard Army maintenance guidelines and procedures established for the equipment under test. Facilities, equipment, instrumentation, and support requirements to accomplish the developmental test should be defined in the test directive or the System Support Package components list; however, if these data are not defined, the following should be addressed as a minimum to support the test:

2.1 Facility.

CHARACTERISTICS	MINIMUM REQUIREMENTS
Operational airfield	As required to support test aircraft
Test flight range	Providing various types of terrain
Aircraft and avionics maintenance support	As required to support aircraft and test equipment
Data reduction and photographic processing facility	As required to support data reduction and analysis plan
Radar equipped flight control facility	As required to verify aircraft flight direction
Electromagnetic Environmental Test Facility	As required to perform EMC/EMV tests

2.2 Equipment.

Maintenance support	Standard Army tool set
Photographic/video	Color camera (motion, still) as required

* Footnote numbers match reference numbers in Appendix G.

Equipment.

Appropriate aircraft and aircraft support equipment	As required to support test
Voice communication network	As required to support test
Equipment required by referenced TOP's	As required
Meteorological equipment	As required
Test equipment	As required

2.3 Instrumentation. As required

2.4 Support Requirements.

2.4.1 Personnel.

Pilots	As required
Maintenance	As required
Instrumentation	As required
Data reduction	As required
Photographic/videc	As required
Test personnel with appropriate skills and specialized training	As required

2.4.2 References.

a. Army Regulation 40-5, Medical Services, Health and Environment, w/TECOM Supplement 1.

b. Army Regulation 70-10, Test and Evaluation During Development and Acquisition of Materiel.

c. Army Regulation 200-2, Environmental Quality, Environmental Effects of Army Actions.

d. Army Regulation 385-16, Systems Safety, Life Cycle Verification of Materiel Safety.

e. AMC Regulation 700-38, w/TECOM Supplement 1 and USAAVNDTA Supplement 1, Test and Evaluation -- Incidents Disclosed During Materiel Testing.

f. DARCOM Regulation 70-8, w/TECOM Supplement 1, DARCOM Value Engineering Program.

g. DARCOM Regulation 385-26, Safety, Aviation Safety, w/TECOM Supplement 1.

h. DARCOM Regulation 700-13, Integrated Logistic Support Performance Evaluation Report, w/TECOM Supplement 1.

i. AMC Regulation 385-12, w/TECOM Supplement 1, Life Cycle Verification of Materiel Safety.

j. TECOM Regulation 108-2, Audio Visual Services; Administrative and Technical Procedures, as implemented by USAAVNDTA Memo 108-1.

k. TECOM Regulation 385-7, Safety, Potential Health Hazards to Humans Participating in Testing.

l. MIL-C-55163, Calibration of Test and Measuring Equipment.

m. MIL-H-46855, Human Engineering Requirements for Military Systems, Equipment and Facilities.

n. MIL-STD-454, Standard General Requirements for Electrical Equipment.

o. MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities.

p. TOP 6-2-507, Safety and Health Evaluation - Communications/Electronic Equipment.

q. TOP 7-3-058, Built-In Test Equipment.

r. TOP 7-3-059, Diagnostic and Inspection Equipment (Aviation).

s. TOP 7-3-519, Photographic Coverage.

t. TOP 7-3-530, Vulnerability and Security (Aviation Materiel).

u. Requirements documents (LR, LOA, ROC, Materiel Needs, etc.).

v. Army Regulation 5-12, Army Management of Electromagnetic Spectrum.

w. MIL-STD-461, Electromagnetic Interference Characteristics Requirements for Equipments.

x. MIL-STD-462, Electromagnetic Interference Characteristics, Measurements of.

y. TOP 6-2-508, Vulnerability, Electromagnetic.

z. TOP 6-2-560, Electromagnetic Compatibility Test.

aa. TOP 6-2-542, Electromagnetic Interference Tests for Electronic Equipment.

bb. TOP 6-2-559, Electromagnetic Radiation Analysis.

3. PREPARATION FOR TEST. This section provides guidance for planning a functional developmental test of aircraft HRSs. Consummate the planning phase with the detailed test plan. The test plan will establish the test methodology and provide the procedures for gathering, reducing, and analyzing data to accommodate each developmental test objective. The test plan will also identify all facility, instrumentation equipment, and support requirements including any specialized training requirements. Follow the appropriate test planning steps as outlined below to insure adequate test controls and a complete, thorough, and cost-effective test.

3.1 Review. Review all pertinent data related to the materiel development test.

a. Requirements documents (LR, LOA, ROC, Materiel Needs, etc.).

b. AMSAA or TECOM IEP/TDP.

c. Applicable materiel available from the procuring agency or developer/contractor such as contractor test plan, contract specification, or military specification.

d. Pertinent reports on previous tests of similar equipment. The Federal Aviation Administration's Technical Center at Atlantic City, NJ, should be contacted for test plans and test reports that may exist on Civil Aircraft HRSs.

e. Any other applicable source of information (ARs, TOPs, TM, etc.).

3.2 Test Objective. Establish the overall test objectives, as outlined in the TECOM test directive and the IEP/TDP. Review the requirements documents for developmental criteria and establish appropriate subtest objectives such as:

a. Initial Inspection. Determine the condition and completeness of the HRS in accordance with TOP 7-3-503.[3] Perform the following as a minimum:

(1) An inventory check against the basic issue item list (BIIL). Submit an equipment performance report for any discrepancies.

(2) Remove all protective coverings and preservatives, and inspect for defects.

(3) Check for completeness of assembly.

(4) Examine the system support package for completeness, discrepancies, or defects.

b. Physical Characteristics. Determine the physical characteristics of the heading reference equipment in accordance with TOP 7-3-500.[4] Perform the following as a minimum:

(1) Photograph as appropriate and note the legibility and effectiveness of the equipment's legends, markings, etc.

(2) Determine the physical dimensions, weight, and volume of all subsystem components.

(3) Determine the weight of the total system.

c. Installation Characteristics. Determine the installation/removal characteristics of the heading reference equipment in accordance with TOP 7-3-502.[5] Perform the following as a minimum:

(1) Evaluate the installation instructions for accuracy and completeness in accordance with TOP 1-2-609.[6]

(2) Evaluate the installation technique and mounting provisions to protect the equipment against shock and vibrations, as applicable.

(3) Evaluate all subsystem, system, or equipment interfaces (plugs, cables, connectors, etc.) for positive response and secure locking.

(4) Evaluate the system/component installation characteristics for ease and quickness. Assess the following:

(a) Accessibility.

(b) Mounting flexibility.

(c) Quick disconnect design.

d. Compatibility. Determine if the HRS is compatible with each aircraft for which it was designed, compatible with the mission objective of the designated aircraft, and compatible with all other instruments and equipment on the designated aircraft. Do this in accordance with the compatibility TOP 7-3-509.[7]

e. Performance Test. Determine the adequacy and suitability of the heading reference equipment to perform its intended function in operational environments and flight modes which represent or simulate those in which the designated aircraft is expected to perform. Follow the testing procedures as presented in paragraph 5, Test Conduct, this TOP. Pay particular attention to the lighting and HFE considerations. If instrumentation of the aircraft is required to verify the performance sensitivity of the test equipment, see TOP 6-3-526.[8]

f. Electromagnetic Compatibility. As required, determine the ability of the HRS to operate in its intended electromagnetic environment without performance deggadation to or from its environment. Do this in accordance with TOP 6-2-560.[9]

g. Electromagnetic Vulnerability. As required, determine the vulnerability of the HRS to jamming, intercept and direction finding in the intended environment. Do this in accordance with TOP 6-2-508.[10]

h. Electromagnetic Interference. As required, determine the unintentional emissions and susceptibilities of the HRS. Do this in accordance with TOP 6-2-542.[11]

i. Reliability. Evaluate the reliability characteristics of the HRS in accordance with TOP 7-3-508.[12]

j. Logistics Supportability. Assess the logistics supportability of the test item in accordance with TECOM Supplement 1 to DARCOM Regulation 700-15.[13] As a minimum, determine the following:

(1) Maintenance characteristics of the test item. (See TOP 7-3-507.[14])

(2) Adequacy of the technical manuals. (See TOP 1-2-609.[15])

(3) Scope of training required to effectively and efficiently operate and maintain the test item. (See TOP 7-3-501.[16])

k. Human Factors and Lighting Characteristics. Assess the heading reference pilot display equipment for readability characteristics and for a positive response reaction to the data displayed. (See TOP 1-2-610[17] and TOP 7-3-527.[18])

l. Safety. Identify and evaluate any characteristic of the HRS which could lead to a flight safety consideration. Such a condition could result from insufficient or extraneous information as well as critical information grouping/layout or display technique. Insure that all failure modes are fail-safe. (See TOP 7-3-506.[19]) Hazards will be evaluated and classified in accordance with TOP 1-1-012[20] and MIL-STD 882A.[21]

3.3 Schedule. Prepare a detailed test time line depicting each test associated event which must occur to accomplish the test objectives and to insure facilities, logistics, personnel, and support equipment are available in a time frame conducive to accomplishing a comprehensive and cost-effective test. The time line should show sufficient time periods allotted to accomplish each test objective, insuring that adequate amounts of test data are taken to project required statistical confidences to the test results. The following schedule items should be addressed as a minimum:

a. Facility. Schedule the applicable facility requirements presented in paragraph 2.1. Facility requirements associated with adverse flight conditions due to meteorological/environmental considerations should not be overlooked. Flights at night and, in particular, under instrument meteorological conditions (IMC), place the greatest demand on the heading reference system.

b. Instrumentation Equipment and Support. Schedule, as applicable, instrumentation support test equipment and support requirements as presented in paragraphs 2.2, 2.3, and 2.4.

c. Logistics. Schedule logistics requirements, as appropriate, including ground handling equipment, administrative transportation of both personnel and equipment, aircraft fueling, and other servicing accommodations.

3.4 Plan of Test. Develop a detailed test plan in accordance with TECOM Regulation 70-24.[22] This plan will provide the test data requirements and the data collection procedures to satisfy each test objective.

3.5 Test Safety. Assess any potential safety consideration for test personnel and equipment. Take appropriate steps (training, safety checklist, posters, etc.) to insure that the safety measures are observed throughout the test. Acquire any test safety assessments and/or safety/airworthiness releases.

3.6 Environmental Impact. Determine if there are any environmental considerations. If environmental considerations exist, develop procedures or outline precautions to be observed to protect the environment.

a. Review the Environmental Impact Assessment Life Cycle (EIALC) or waiver provided by the developer/sponsor to determine applicable environmental quality considerations.

b. Consult the onsite installation environmental coordinator as to appropriate environmental quality protection measures.

3.7 Security. Security safeguards for the United States Government and for proprietary rights of the test materiel developer must be considered early in the test planning stage. The following steps must be taken:

a. Consult the security classification guide for the project, as appropriate.

b. Consult the primary test agency security representative for security guidance. Coordinate with security personnel of other test support agencies (developer) and industry, as appropriate.

c. Take appropriate security measures throughout the test to safeguard intra-industry proprietary rights and to safeguard the security of Government property.

4. TEST CONTROLS. The developmental reference heading test will be conducted and test data will be recorded in strict compliance with the TECOM test directive, IEP/TDP. If specific directions are not available, the following guidelines will prevail:

a. Reduce measurements to universal metric and English units.

b. Round out numerical observations to the nearest tenth.

c. Report time to the nearest hundredth of an hour.

d. Accomplish and record physical characteristics in compliance with TOP 7-3-500.[23]

e. Instrumentation and test equipment must be properly calibrated and have a current calibration certificate.

f. Conduct all tests and collect data in compliance with prescribed and/or standard procedures and when deviations are required, coordinate with the TECOM project officer; justification will be documented.

g. Record and process all data in a timely fashion.

h. Assign only properly trained and qualified personnel to participate in the conduct of the test. In particular, pilot qualifications/capability must reflect the expertise necessary to fly the test flight profiles with precision and safety.

i. Conduct the functional heading reference test in a test environment representative of the operational environment intended for its use.

j. Conduct each test run under documented conditions, such that the test results could be duplicated or compared.

k. Follow the detailed test plan; document any deviations from same. Avoid nonessential test delay due to aircraft scheduled maintenance. This can be accomplished through coordination and planning.

5. TEST CONDUCT. It is essential that the HRS demonstrate heading accuracy and flight performance characteristics in accordance with the development document. The flight performance test will concentrate on evaluating these characteristics within the mechanical, atmospheric, and electromagnetic environment of the aircraft's mission. The conduct of this subtest will be performed in compliance with the TECOM test directive, IEP/TDP. However, if specific guidance is not available, the following general guidance and specific test methodology will be used to evaluate the heading accuracy and flight performance of the HRS.

5.1 Performance Test Preparation. Establish specific test procedures to evaluate the flight performance of the HRS within the scope of this TOP.

a. Determine specific characteristics from the criteria documents that the test item HRS must demonstrate in the development flight test environment.

b. Prepare an aircraft flight profile in accordance with the IEP/TDP requirements, reflecting specific flight modes and characteristics which will exercise each characteristic of the HRS.

c. Install, check out, and calibrate the heading reference equipment in accordance with the installation instructions. Insure input and output signals are within specified limits and that no operational hazards exist.

d. Install, check out, and calibrate test instrumentation as required to record test flight data. Photographs, motion picture, and/or magnetic tape recordings are conventional methods of collecting performance data for comparison and validation purposes.

e. Calibrate all test equipment and instrumentation in accordance with TECOM Supplement 1 to AR 750-25.[24]

f. Establish geographically calibrated test courses to accommodate the navigational courses and special maneuver areas which can accommodate the following test profiles:

(1) Straight and level flight.

(2) Contour flight.

(3) Nap-of-the-Earth (variable acceleration and abrupt changes in direction).

(4) Special maneuvers, in an isolated magnetically uniform area as determined by a magnetic survey.

g. Insure adequate data are recorded during each flight profile to provide credibility as to the accuracy or discrepancy of the HRS. Provide a qualitative description of the flight procedures and each event by qualified observer to support the independent quantitative output of certified instruments of known characteristics and accuracy used to evaluate performance. Make preparations to record aircraft actual and indicated position, distance flown, and heading at each checkpoint.

h. Plan to perform an equipment calibration check and test item functional check prior to and following each test flight and record the following information:

(1) Test run and sequence number description.

(2) Test item nomenclature and serial number.

(3) Characteristic of the HRS to be evaluated during the particular test run.

(4) Results of equipment calibration check and test item functional test.

(5) Meteorological condition.

5.2 Preoperational Tasks. Perform the following procedures, noting that for systems already installed only procedures c through h are required. Note any difficulties experienced during any of the procedures.

a. Depreservation - remove all preservative.

b. Assembly - attach any items removed for transporting convenience. List each item involved.

c. Lubrication - verify completeness of the lubrication program.

d. Power Requirements - verify power input circuitry and note the electrical power requirements of the system. Insure that all requirements are satisfied by the electrical systems available on the type of aircraft on which the test item will be utilized.

e. Installation - perform the procedures required by TOP 7-3-502[25] and the following:

(1) Examine the instructions given for the mounting of all equipment for completeness.

(2) Insure the equipment is protected against shock and vibration, if required.

(3) Check all cables, connectors, and plugs for positive, secure locking and keying.

(4) Examine the installation procedures for fast replacement of the system, e.g., quick disconnect fittings for cables, etc.

f. Controls, adjustments, and indicators (mechanical and electrical) - note the following:

(1) For each control, adjustment, and indicator, determine the following as appropriate:

(a) Operation is correct.

(b) Effect on the system is as required.

(c) Absence of binding and rubbing.

(d) Calibration is proper.

(e) Changes are monitored and displayed correctly.

(f) Range is correct.

(2) List any discrepancies.

(3) Evaluation of components requiring flight conditions will be attained during the performance test.

g. Test item protective and safety devices such as limit, overload, and interlock switches for proper operation.

h. Systems equipped with confidence, self-check, or integrity circuits shall be verified.

i. All system input/output voltages will be verified and recorded.

5.2.1 Data Required - Preoperational Tasks. For each preoperational task, record the personnel, materials, equipment, tools, man-hours, etc., required to accomplish each task and qualitatively assess the following:

a. Depreservation procedures utilized.

b. Any items which require assembly.

c. Lubrication procedures performed.

d. Any instances where the electrical requirements of the equipment cannot be satisfied by the aircraft's electrical system or indications that power input circuitry is incorrect.

e. The data required by TOP 7-3-502[26] and any indications of the following:

(1) Mounting for shock and vibration not sufficient.

(2) Insecure connectors.

f. For all controls and indicators, list any of the following conditions:

(1) Improper operation.

(2) Desired effect on test item not indicated.

(3) Binding, rubbing, and jerking in motion.

(4) Improper calibration.

(5) Proper monitoring and display of system conditions not shown.

(6) Range too small, too large, etc.

g. List any protective or safety device which does not operate properly.

h. Any problems encountered in the operation of self-checking circuits or ground tests of system.

5.3 Performance Test Conduct. This section will establish test procedures to assess the performance of the HRS under dynamic flight conditions. In all probability, a modernHRS will have integrated the characteristics of a magnetic azimuth detector (MAD) and a precision directional gyro (DG) into an electronic package with self-calibration capabilities and built-in test equipment (BITE) features. Such a system would have a sophisticated control system giving the operator an option of several primary and secondary operational modes which utilize various combinations of the HRS independent components. Typical operational modes for such a system are (a) slaved gyro, (b) free gyro, and (c) compass. Each of these operational modes will be generally discussed and a typical test objective and associated test methodology will be presented in subsequent paragraphs under appropriate headings. Self-calibration capability and BITE features are unique applications of the system characteristics/capability and will be tested in concert with the system component/operational mode generally affected.

5.3.1 Special Features.

5.3.1.1 Self-Calibration. Self-calibration is the inherent capability of the development system to self-align its HRS to north, true, or magnetic depending upon the sophistication of the mechanical components and electronic circuitry. Generally, specifications will reflect accuracies within a fraction of a degree, to be accomplished within a minimum clock time and specified number of compass swings. To assess this capability, the testers need only to follow the calibration instructions and verify the accuracy. However, to verify the accuracy of the system is not an easy task because of the inherent inconsistency of the earth's magnetic field due to local geographic phenomena and man-made structures. State-of-the-art technology in inertial navigation systems (INS) can accomplish this task to arc second accuracy.

5.3.1.1.1 Test Conduct. Establish the centerline of the aircraft along the longitudinal axis. This centerline will serve as a reference line for installation and alignment of all systems components sensitive to alignment errors. Install an INS of required accuracy into the testbed aircraft. Mechanically align the inertial platform with the reference centerline of the aircraft. Use the inertial system itself to align the platform and secure the system in place. Mechanically align the MAD with the aircraft centerline; at this point, both systems are indexed to the same reference. The INS can be used to provide heading (azimuth) information to align the MAD. The preferred alignment will be accomplished with all systems activated and the rotor system turning. A precision auxiliary heading indicator will be installed for each system with readout graduations consistent with the heading accuracy required. The heading indicators will be stacked to minimize parallex in full view of the pilot, observer, and a video camera.

5.3.1.1.2 Data Acquisition Procedures. Maneuver the aircraft to a Universal Transverse Mercator (UTM) geographically surveyed position located in an area which has been magnetically surveyed and is known to have a uniform magnetic variation within .1 degree. Designate this area as the calibration base (Cal Base) station. The magnetic survey can be accomplished with a Sperry MC-2 compass calibrator or equivalent equipment. Having previously calibrated and verified the INS to a known accuracy at the Cal Base UTM position, perform an 8-point compass swing to verify the integrity of the INS system (record each azimuth direction ψ_A). Disregarding the INS, perform the calibration procedures outlined in the operational instructions for the test HRS. Record appropriate data as presented in paragraph 5.3.1.1.3. These procedures should be accomplished with all systems activated and rotor system turning. To assess the effectiveness and accuracy of the calibration procedures, perform a minimum of two 8-point compass swings recording all data defined in paragraph 5.3.1.1.3. These data will be analyzed and used to assess the calibration accuracy.

5.3.1.1.3 Data Required. A data acquisition package will be installed with a digital recorder system capable of recording multiple channels (as required) simultaneously at a minimum sample rate of 20 samples/second. Appendix C presents a typical instrumentation package for recording data during flight test. To be recorded are the output signals of the (a) test HRS, (b) MAD, (c) DG, (d) INS, (e) input azimuth signal to a navigational system such as the AN/ASN-128 Lightweight Dopler Navigation System (LDNS), aircraft acceleration data. Specific data include, but are not limited to, the following:

1. Time of day.
2. Date and calibration.
3. Location lat. long. (UTM coordinates).
4. Magnetic variation.
5. Number of compass swings.
6. Time required to complete calibration.
7. Heading input signal ψ to test system pilot's display.
8. Output azimuth signal ψ_1 of test system MAD.
9. Output azimuth signal ψ_2 of the test system DG.
10. Output azimuth signal ψ_A of the INS (standard).
11. Input azimuth signal ψ_B to the LDNS.
12. Accelerations:
    - Aircraft pitch θ
    - Aircraft yaw $\propto$
    - Aircraft roll ϕ
13. Clock.

5.3.1.1.4 Data Analysis. The output of the INS system will serve as the standard against which all other heading parameters will be assessed. Typical comparisons of system calibration accuracy are as follows:

1. $\Delta\psi = \psi_A - \psi \pm$ Mag Var
2. $\Delta\psi_1 = \psi_A - \psi_1 \pm$ Mag Var
3. $\Delta\psi_2 = \psi_A - \psi_2 \pm$ Mag Var
4. $\Delta\psi_3 = \psi_A - \psi_3 \pm$ Mag Var

Where ψ = Heading azimuth input to pilot display for test system.

ψ_1 = Heading azimuth output of MAD (test system).

ψ_2 = Heading azimuth output of DG (test system).

ψ_A = Heading azimuth (INS).

ψ_B = Input heading azimuth (LDNS).

$\Delta\psi$, $\Delta\psi_1$, $\Delta\psi_2$, $\Delta\psi_B$ = azimuth error deviation from ψ_A (azimuth INS).

An attempt should be made to correlate azimuth heading anomalies to aircraft's accelerations (pitch, roll, or yaw).

5.3.1.2 Built-In Test Equipment (BITE). System BITE is as varied as the system components and circuitry comprising the test item. In general, the BITE system injects a test signal which interrogates each major component and integrated circuitry of the HRS and provides an indication as to its operational status. The sophistication of such a system is delineated in the requirement and specifications documents. Verification of their incorporation and their functional adequacy is the primary objective of the developmental tester.

5.3.1.2.1 Test Conduct. Verify the circuitry and operational characteristics of the BITE at the beginning and end of the test program. Methodically disable each circuit and/or subsystem which is monitored by the BITE, simulating single and multiple system failures. This approach is required to insure a complete evaluation of each failure mode. Continual evaluation will be accomplished as the test progresses and random failures occur.

5.3.1.2.2 Data Acquisition Procedures. Under normal/appropriate operational conditions, cause predetermined malfunctions to occur to the test system. Do this at the beginning and end of test. Record each set of circumstances, effect on the system, and BITE indication. Compare the two sets of data for consistency. The end of test data set will also serve as a final system integrity test. In addition to the simulated failure tests, the system's BITE system will be exercised each time the test system is operated. A test record log will be kept showing each interrogation and appropriate results. Operations of the BITE system will be accomplished in accordance with the operational instructions provided with the test system.

5.3.1.2.3 Data Required. The following data are required for each interrogation of the BITE system. Complete Data Form (appendix B).

a. Date, time, place.

b. Circumstances of BITE interrogation.

c. Results (BITE system indication).

d. Verification of results.

5.3.2 Slaved Gyro. The slaved gyro operational mode is the predominant usage mode except in the extreme northern and southern latitudes where the earth's magnetic flux lines converge causing the MAD to be unreliable. In this mode of operation, the HRS free gyro subsystem is electronically coupled to the HRS MAD subsystem to take advantage of the inherent short term accuracy of the free gyroscope and the long term accuracy of the MAD. Typically, in this mode of operation, an electronic integration unit is required. Its primary function is to compare heading azimuth angles between the gyro and MAD and, under specified and stabilized conditions, torque or slave the gyroscope output to the azimuth angle of the MAD. For this to occur, aircraft's three axial accelerations must be monitored in order to filter out erroneous data introduced during periods of gyro and/or MAD instability. A smoothing process must be accomplished to filter out the oscillatory signal inherent to a pendulous instrument which is a characteristic of the MAD. A general discussion of typical system errors is provided at appendix F.

5.3.2.1 Test Conduct. The primary objective of this subtest is to evaluate the ability of the developmental HRS in the slaved gyro mode to deliver accurate and consistent heading information under specified flight conditions. Results will be compared to developmental criteria and subsystem specifications. Consistent with the philosophy and test methodology established in paragraph 5.3.1, Special Features, plan and execute a test flight program which will determine the accuracy,stability and consistency of the HRS in the slaved gyro mode of operation. The flight profiles will take into account the inherent error sources of a typical HRS as presented in appendix C. Appendix D presents one basic high dynamic flight (Profile A) and a potential variation thereof (Profile B) which are suitable to accomplish the developmental test objective. The basic Profile A consists of four independent legs, terminated at easily recognizable geographical landmarks which have UTM grid coordinates surveyed to an accuracy of ten meters. Each terminal point will be in an isolated, magnetically quiet area known to be free of local magnetic biases with a known magnetic variation. Each flight profile will begin and end at the calibration site (Cal Base) discussed in paragraph 5.3.1.1.2. Other terminal points will be designated as checkpoints 1 through 4. It should be noted that checkpoints 1 through 4 are positioned geographically such that the major cardinal headings are negotiated for each Profile A or B. Using terminal checkpoints 1 through 4, a number of profiles could be determined; however, a minimum of two different profiles will be flown. Profiles A and B are typical examples. Each checkpoint 1 through 4 will be separated by a minimum of ten nautical air miles. Appendix E presents a description of four high dynamic maneuvers which are basic to aircraft flight and which greatly affect aircraft HRSs performance. The HRS in the slaved gyro mode of operation typically operates in two capacities: (a) As a subsystem, providing heading reference information to a navigation system such as the AN/ASN-128 LDNS; and (2) Independent HRS, providing heading information directly to the pilot. For either case, the HRS must demonstrate the qualities of accuracy and stability in accordance with developmental specifications. In addition, for the subsystem mode of operation, the HRS must demonstrate compatibility to interact accurately and consistently with the designated navigation system. To evaluate this requirement/specification, the test HRS must demonstrate this capability. Typically, a performance comparison to an existing unit such as the AN/ASN-43B HRS with known characteristics and accuracy is required. To accomplish the objective, parallel systems methodology will be utilized. Install two independent navigational systems such as the LDNS into the testbed aircraft; one system will be driven by the test HRS and the other system will be driven by the known HRS. Identical installation and installation flexibility are required to allow the HRS driving the INSs to be switched between profiles. This is required to isolate installation and navigation system biases from the HRS evaluation. As in paragraph 5.3.1.1.1, install an INS of known accuracy to provide the true azimuth heading which will be the standard against which the test HRS azimuth accuracy will be measured. Again, all system components subjected to alignment errors will be indexed to the centerline of the aircraft. The INS will be utilized to accomplish and verify the systems alignment. With all systems installed according to specifications and the flight profiles established (appendix D), perform the following: Maneuver the aircraft to the Cal Base station. Perform an 8-point compass swing maintaining each heading for a duration to activate all aircraft flight systems, communication and navigation equipment, singularly and in mission related combinations. This should be done methodically in accordance with a predetermined plan to assure all options and range settings are utilized. Electromagnetic interference is of particular concern, and if any indication of interference is evident during this abbreviated compatibility test, proceed with an in-depth evaluation in accordance with paragraphs 3.2f, 3.2g, and 3.2h, this TOP. A video camera (see paragraph 5.3.1.1.1) will be installed and utilized to record visual conformation of any anomaly depicted through the system's pilot displays. A system's calibration and compatibility check will be accomplished as a first and last step in the execution of each flight profile. All data parameters presented in the calibration subtest, paragraph 5.3.1.1.3 will be recorded. (See appendix B.)

5.3.2.2 Data Acquisition Procedures. Accomplish paragraph 5.2, Preoperational Tasks, as applicable. Maneuver the testbed aircraft to Cal Base station. Perform the calibration/compatibility check described above. Set the exact UTM coordinates for the Cal Base station into each navigational system (INS, LDNS/test HRS, LDNS/known HRS). Dial/set into the INS the UTM coordinates for each checkpoint 1 through 4 for Profiles A or B (appendix D), as applicable. Proceed to fly the designated profile using the navigational capability of the INS. At each checkpoint, record the UTM position coordinates' output from each navigational system (INS, LDNS/test, LDNS/known HRS). Using the INS as the position standard, resolve the long and cross-track errors as a function of distance travelled for each of the LDNSs. Navigational accuracy and compatibility comparisons can be made from these data. Continuously record all directional azimuth and aircraft acceleration data required in paragraph 5.3.1.1.3. These data will be used to determine heading azimuth accuracy of the test HRS and to correlate heading anomalies to aircraft acceleration, as required. Fly Profiles A and B two times each; between like profiles switch the test HRS to the opposite LDNS as discussed above. If anomalies, i.e., shift in accuracy, stability, or consistency are experienced as a result of the LDNS/HRS switch, examine each system installation procedure and setup for inconsistencies. If the problem is not with the installation technique or layout, continue to isolate navigational/HRS parameters and examine system output data to isolate and evaluate the extent of the problem. Fly Profiles A and B two additional times each. Perform several special high dynamic maneuvers (appendix E) between each checkpoint, i.e., the roller coaster between checkpoints 1 and 2, snake between 1 and 4, acceleration/deceleration between 2 and 4, figure 8's between 4 and 3, etc. Parameter comparison between the first and second set of profiles will isolate navigational errors due to the high dynamic maneuvers. UTM position update will be accomplished at each profile checkpoint. Fly one last profile at three aircraft airspeeds, 40K, 80K, and 120K, as safety of flight conditions dictate. The profile will initiate and terminate at Cal Base with the performance of the 8-point compass swing and compatibility check, as defined above. The profile will be flown at a minimum safe altitude AGL. This profile is designed to simulate a NOE flight and will utilize as a minimum, one leg between two of the established (1-4) checkpoints. Two each of the high dynamic maneuvers (appendix E) will be performed enroute both directions between the designated checkpoints. UTM position coordinate will be recorded and navigational update will be accomplished at each checkpoint. Data required in paragraph 5.3.1.1.3 will be recorded at a data rate of 20 samples per second throughout the flight. Delta azimuth calculation presented in the Data Analysis paragraph 5.3.1.1.4 will be accomplished to determine the heading accuracy of the test HRS. Appendix D, Profile C, depicts a typical profile as defined.

5.3.2.3 Data Required.

- All data required in paragraph 5.3.1.1.3.

- Time marked data (data snapshot), i.e., specific data correlated to a known time interval and event such as an 8-part compass swing or calibration check.

- Explanatory comments, defining and correlating time marked data to physical flight events.

5.3.2.4 Data Reduction and Analysis.

- All data will be screened to verify a good and complete set of data are recorded for each test event.

- All data will be time and event correlated.

- Delta azimuth calculation presented in Data Analysis paragraph 5.3.1.1.4 will be done for each data point (20 data points/second).

- Delta azimuth data will be arithmetically averaged into one data point per second. The maximum delta azimuth processed during each second (20 points) of data will be captured for further analysis to answer specific criteria concerning maximum acceptable azimuth errors. Correlation to aircraft acceleration will be determined as required.

- UTM position and delta azimuth data will be summarized and correlated to specific flightprofiles flown.

- Statistical values of heading errors in degrees (standard deviations, route mean square (RMS), mean value, etc.) will be calculated from delta azimuth data (see paragraph 5.3.1.1.4).

- Calculate navigational accuracies (along track error, cross-track error, radial error) utilizing UTM position data recorded in the slaved gyro mode of operation, paragraph 5.3.2. Navigational accuracy data can be grouped and statistically analyzed to answer critical issues pertaining to equipment performance of the test HRS.

5.3.3 Compass Mode. The compass mode of operation is typically a backup navigation aid utilized primarily under emergency conditions (failure of the primary system). In this mode, the system reverts back to the very basic magnetic compass sensitive to the earth's magnetic field, and subject to the error sources of the MAD discussed at appendix F.

5.3.3.1 Test Conduct. Heading accuracy, stability, and consistency of the system are central to a developmental test objective. To evaluate these characteristics the test methodology developed for the slaved gyro mode of operation, paragraph 5.3.2, is appropriate with a somewhat reduced scope to reflect only the heading azimuth output of the MAD. The data acquisition procedure, data required, and data reduction procedure of paragraphs 5.3.2.2, 5.3.2.3, and 5.3.2.4 are equally applicable, respectively.

5.3.3.2 Data Acquisition Procedure.

See paragraph 5.3.2.2.

5.3.3.3 Data Required.

See paragraph 5.3.2.3.

5.3.3.4 Data Reduction and Analysis.

See paragraph 5.3.2.4.

5.3.4 Effects of Atmospheric Condition. Perform selected procedures of paragraphs 5.3.1 and/or 5.3.2 and 5.3.3 during periods when change in atmospheric conditions exist to determine the effects on performance characteristics. These periods and/or conditions shall include:

a. Night hours.

b. Hours at sunrise and sunset.

c. Poor weather conditions (rain, fog).

d. High and low temperature.

5.4 Post-Test Evaluation. Perform the following:

a. Visually inspect the heading reference system with special consideration given to the following:

(1) Loose chassis components.

(2) Loose or missing hardware.

(3) Broken fasteners or seams.

(4) Discoloration due to effects of heat, rust or corrosion.

(5) Loose connectors or cables.

b. Verify test item protective and safety devices such as limit, overload, and interlock switches for proper operation.

c. Verify, if applicable, proper operation of self-check, or integrity circuitry.

d. Verify all system input/output voltages are correct.

e. Compare results with those recorded in the preoperational tasks and note any discrepancies.

5.4.1 Data Required. Accomplish the following:

a. Record the nature and location of any of the following:

(1) Loose components, hardware, and connectors.

(2) Discoloration.

(3) Broken or worn components.

b. Record any discrepancies in the results of the preoperational and post-test evaluation for the following:

(1) Test item protection and safety devices.

(2) Self-check, or integrity circuitry.

(3) Input/output voltages.

6. DATA REDUCTION AND PRESENTATION. Data reduction/presentation and analysis will be in accordance with the TEP/TDP, and TECOM Pamphlet 70-3.[27]

6.1 Data Reduction. Identify (photograph, etc.), organize, and correlate raw test data by parameter groupings and test run. As required, convert raw test measurements to engineering units. The test data will be analyzed to determine to what degree the test item and its system support package meet the requirements of QMRs, SDRs and detailed military specifications. As a minimum, perform the following:

6.1.1 Slaved/Subsystem Mode of Operation. Using the UTM position data recorded for each test trial and through triangulation, determine navigational accuracies (along track errors, cross-track errors, and radial errors) for test trial flown. Calculate statistical values (standard deviations, RMSs, mean values, etc.) of heading errors as correlated to profile, high dynamic maneuver, heading azimuth, etc. Determine the navigational circular error probability of the test HRS as a function of distance flown. Assess that portion of the navigational error which can be attributed to the primary navigational system. Calibration data, equipment specification, and operational experience will help define this error. The difference between the total navigational error computed from test data and the inherent error of the primary system is assumed to be the accuracy of the test HRS.

6.1.2 Independent Mode of Operation. The test HRS navigational error can be assessed utilizing the UTM position data and through triangulation calculations as determined in paragraph 6.1.1 above. The cross-track error data and the distance flown can be utilized to compute navigation error in degrees as the arc tangent of the ratio.

6.2 DATA PRESENTATION.

a. Prepare a narrative of the test results to include diagrams, photographs, tabular, and other reduced data as required, to support the test conclusions and recommendations. Establish the degree to which the test item satisfies the test criteria or specifications in the operational environment. Provide a recommendation as to the suitability of the test item and its system support package for use by the Army.

b. In the instance of a total or partial failure of the test item to perform its intended function, assess the implications of the failure and present recommendations as applicable.

Recommended changes to this publication should be forwarded to Commander, US Army Test and Evaluation Command, ATTN: DRSTE-AD-M, Aberdeen Proving Ground, MD 21005. Technical information may be obtained from the preparing activity: Commander, US Army Aviation Development Test Activity, ATTN: STEBG-MP-QA, Fort Rucker, AL 36362. Additional copies are available from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, VA 22314. This document is identified by the accession number (AD No.) printed on the first page.

APPENDIX A-1

PRETEST CHECKLIST

TESTING HEADING REFERENCE SYSTEM

1. Have facilities, test equipment, instrumentation, and support requirements been scheduled or secured? See paragraphs 2 through 2.4.2, this TOP. Yes_____No_____.

2. Has appropriate test planning been accomplished in accordance with paragraphs 3.1 through 3.7, this TOP? Yes_____No_____.

3. Have test control measures been implemented such that test results could be duplicated or compared? See paragraphs 4a through 4k, this TOP. Yes_____No_____.

APPENDIX A-2

POST-TEST CHECKLIST

TESTING HEADING REFERENCE SYSTEM

1. Have test data been collected, recorded, and presented in accordance with this TOP? Yes_____ No______. Comment: ____________________________

____.

2. Have all data collected been reviewed for correctness and completeness? Yes_____ No_______. Comment: ____________________________________

____.

3. Were the facilities, test equipment, instrumentation, and support accommodations adequate to accomplish the test objectives? Yes_____ No______.
Comment: ____

____.

4. Were the test results compromised in any way due to insufficient test planning? Yes_______ No______. Comment: ______________________________

____.

5. Were the test results compromised in any way due to test performance procedures? Yes______ No______ Comment: ______________________________

____.

6. Were the test results compromised in any way due to test control procedures? Yes_______ No_______. Comment: ______________________________

____.

7. Were the test results compromised in any way due to data collection, reduction, or presentation technique? Yes______ No_______. Comment:

____

APPENDIX B
DATA COLLECTION FORM
TESTING HEADING REFERENCE SYSTEM

SAMPLE

I. Date________________ Aircraft Tail No.____________

II. Profile No.____________ Test Run Identification____________

III. Test Item Identification:

NOMENCLATURE	MODEL NO.	SERIAL NO.

IV. Data

A. Flight Azimuth Profile

Flight Sequence	UTM Pos.	Grid Az.	Mag A2	Mag Var	Dist (KM)
Cal Base					
to					
Ckpt 1					
to					
Ckpt 2					
to					
Ckpt 1					
.					
.					
.					
to					
Cal Base					

B. Airspeed Profile.

C. Altitude Profile.

D. Maneuver Profile.

E. Recorded Data.

- Heading Azimuth Data
- Aircraft Accelerations

V. Qualitative Comments. ____________________

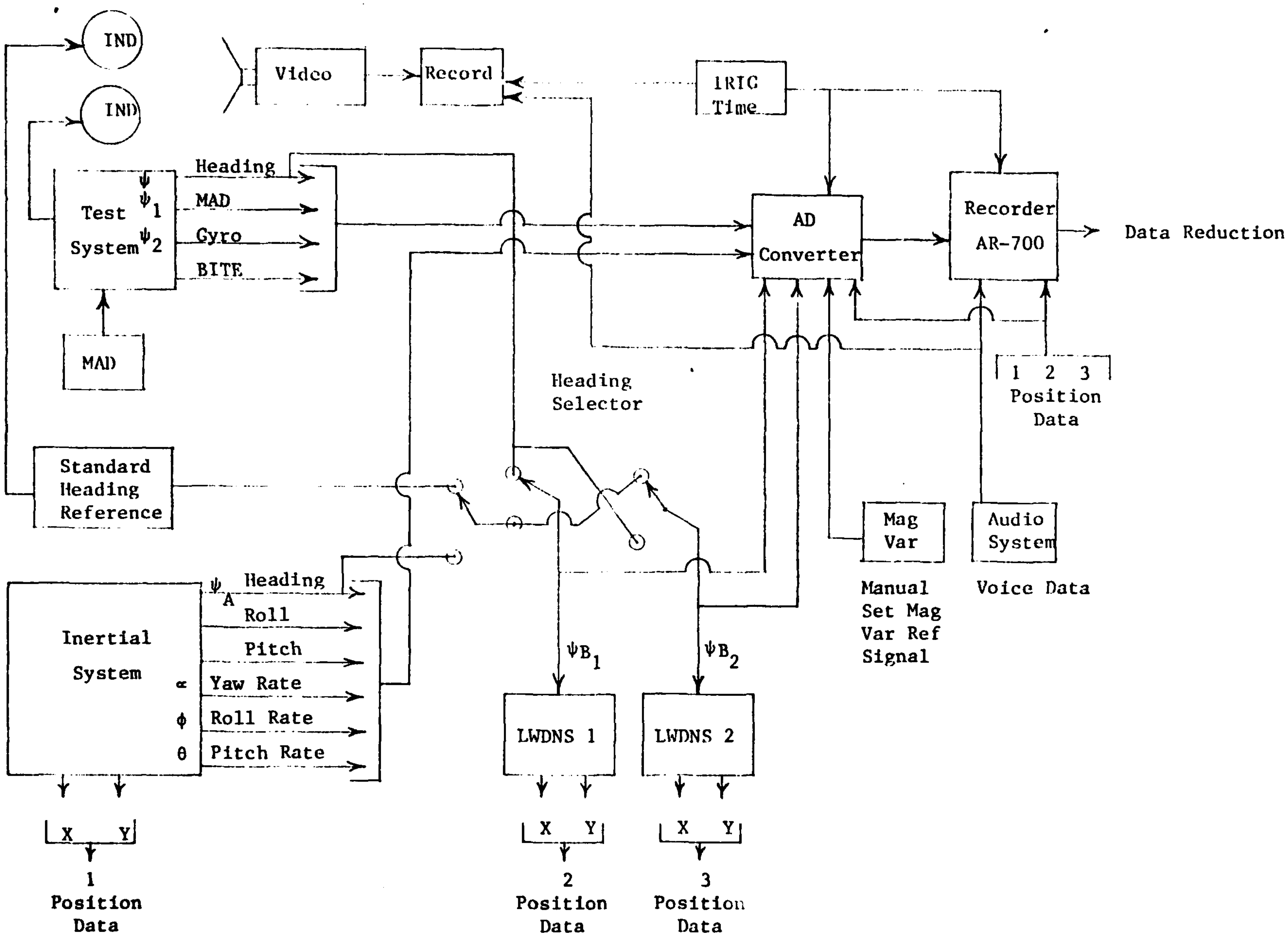
____

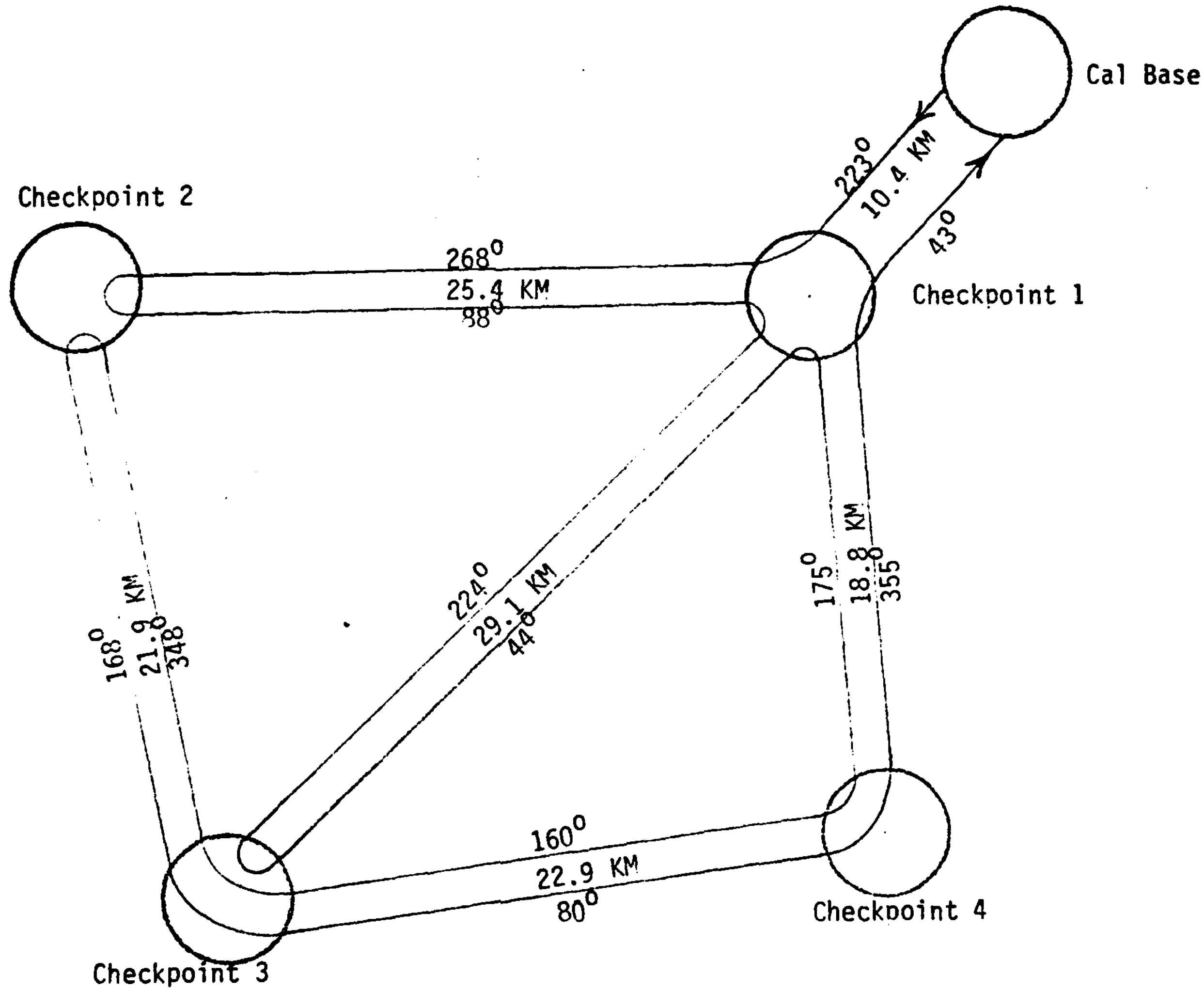
____

____

APPENDIX C

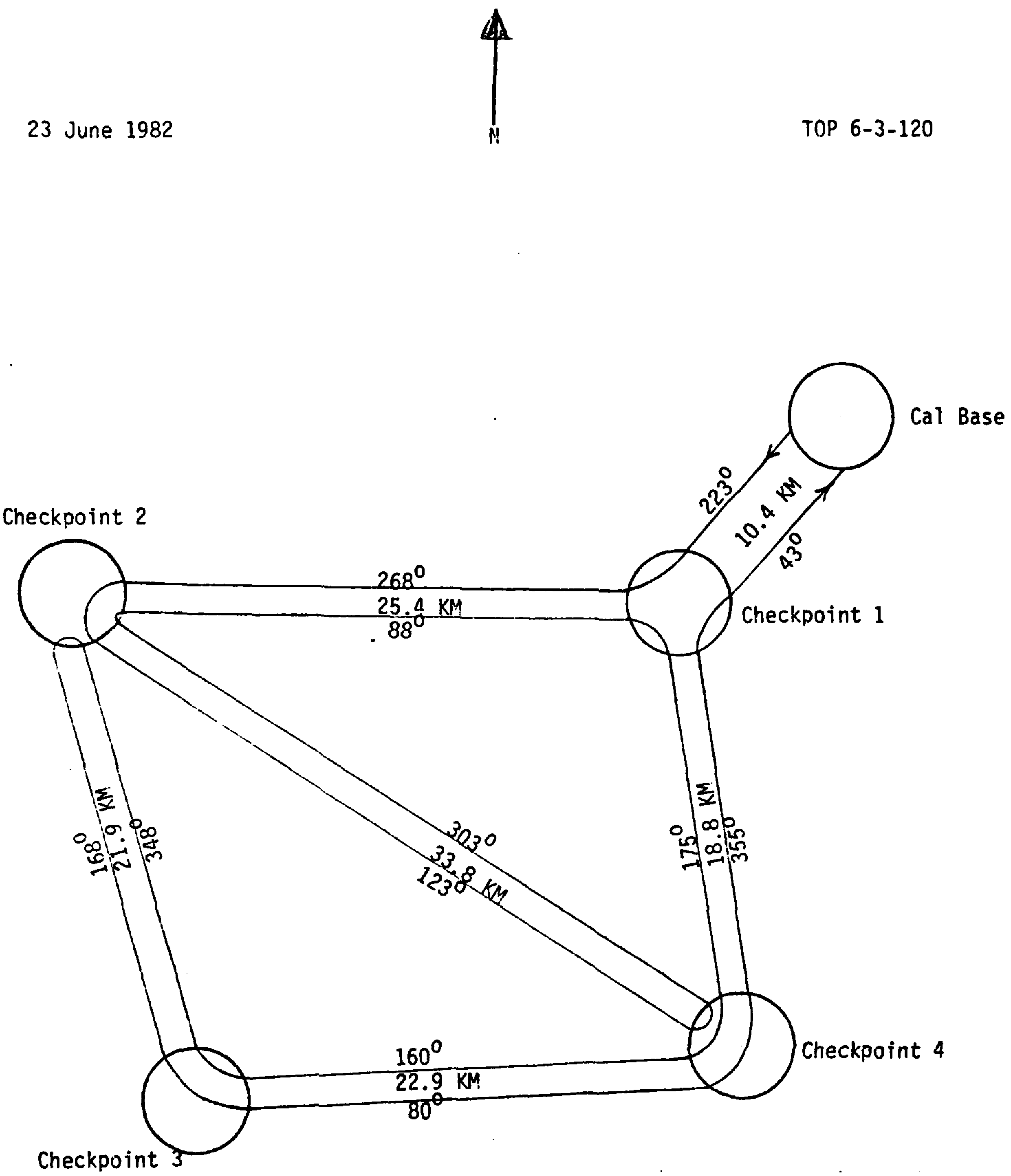
FLIGHT TEST INSTRUMENTATION





PROFILE A

FLIGHT PROFILES

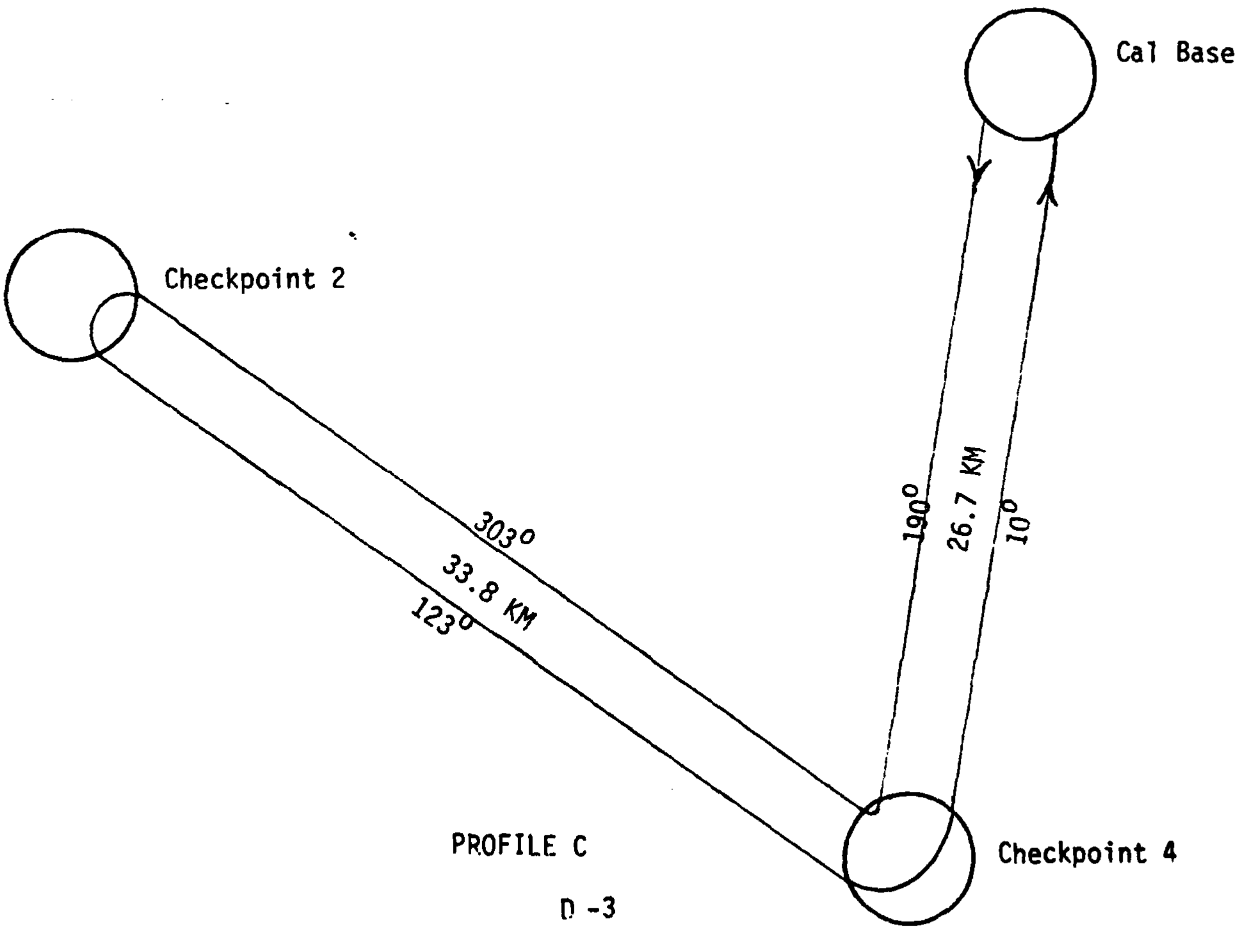

N
Cal Base
223°
10.4 KM
43°
Checkpoint 2
268°
25.4 KM
88°
Checkpoint 1
168°
21.9 KM
348°
303°
33.8 KM
123°
175°
18.8 KM
355°
160°
22.9 KM
80°
Checkpoint 4
Checkpoint 3

PROFILE B

Profile D Description

Airspeed	Altitude	Flight Sequence	Maneuvers *Type	Maneuvers No. Ea.
40,80,120	Min safe	Cal base → Ckpt 4	1,2,3,4	2
		Ckpt 4 → Ckpt 2	1,2,3,4	2
		Ckpt 2 → Ckpt 4	1,2,3,4	2
		Ckpt 4 → Cal base	1,2,3,4	2

*1 Acceleration/Deceleration
 2 Snake
 3 Figure 8
 4 Roller Coaster



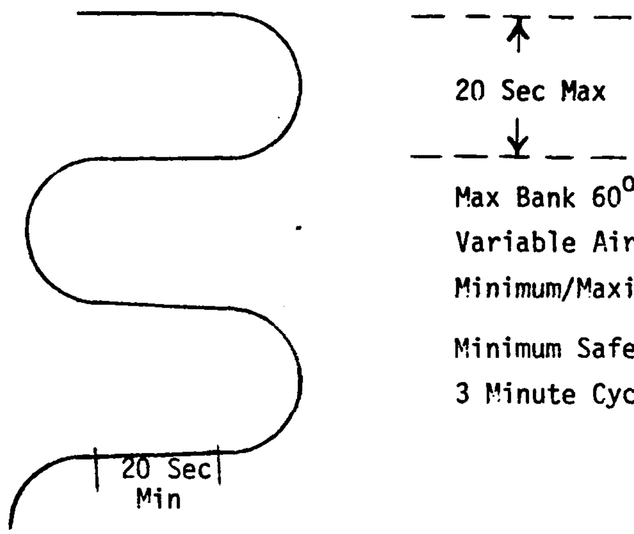
PROFILE C

APPENDIX E

1. Accelerations/Decelerations

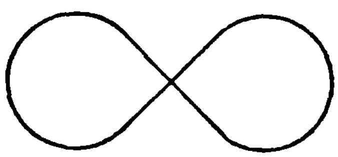
Accel	0 - 100 Knots	2 Minute Cycle
Decel	100 - 0 Knots	Minimum Safe Altitude Above Ground Level

2. Snake



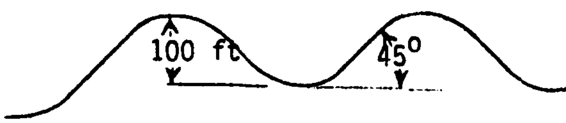
Max Bank 60^{o}
Variable Airspeed
Minimum/Maximum Safe Airspeed
Minimum Safe Altitude Above Ground Level
3 Minute Cycle

3. Figure 8



Max Bank 60^{o}
Minimum/Maximum Safe Airspeed
Miminum Safe Altitude Above Ground Level

4. Roller Coaster



2 Minute Cycle
Max/Min Safe Airspeed
Minimum Safe Alt AGL

HIGH DYNAMIC MANEUVERS

APPENDIX F

TYPICAL HRS SYSTEM ERRORS

1. Directional Gyroscope Error. A free DG provides excellent short term stability in level flight. However, over a long period or during certain maneuvers, it is subject to errors such as those listed below:

a. Gyro Drift - This error is due to torques produced by bearing friction, windage, mass unbalance, etc. The magnitude of the gyro drift and its repeatability varies from gyro to gyro and is quite unpredictable. Fortunately, when operated in the slaved or primary mode the effect of gyro drift is minimal (and may be neglected).

b. Apparent Drift Due to Earth's Rotation - A relative motion occurs between the case and the spin axis of the DG because of the rotation of the earth. This produces what appears to be a heading drift rate. The following equation accurately predicts the value of this heading drift rate:

$$\text{Heading Drift Rate (Deg/Hr)} = 15 \times \text{Sin (Latitude)}$$

Thus, if the above equation is solved with the correct latitude this apparent heading drift error can be eliminated.

c. Apparent Drift Due to Meridian Convergence - Because the earth's meridians converge at the poles, a DG whose heading is referenced to a meridian encounters a change in direction of the heading reference as it moves over the earth. Thus, a relative motion occurs between the meridian and the spin axis which appears as heading drift. By solving the following equation this error can also be eliminated:

$$\text{Heading Drift Rate (Deg/Hr)} = \frac{\text{Ground Speed (Knots)}}{60} \times \text{Sin (Heading)} \times \text{Tan (Latitude)}$$

d. Gimballing Errors - When the case of a two-degree-of-freedom DG is tilted about an axis other than the spin or minor axis, the geometry of the gimballing system requires that the major gimbal rotate through a predictable angle to permit the heading of the spin axis to remain unchanged. The magnitude of this rotation is determined both by the angle of the spin axis with respect to the axis of tilt, and by the magnitude of the tilt. The defining equation is:

$$\text{Tan}\ \psi\ I = \frac{\text{Tan}\ \psi\ \text{Cos}\ \phi - \text{Sin}\ \phi\ \text{Sin}\ \theta}{\text{Cos}\ \theta}$$

Where ψI = Indicated Heading Angle

ψ = Heading Angle

θ = Pitch Angle

ϕ = Roll Angle

e. SLAVED Mode Errors - When operating in the SLAVED mode, the following additional error sources must be considered.

(1) Slaving Offset Error - Slaving offset error results from the need for an error signal from the compass transmitter to counteract the real and apparent drift rates of the DG. This offset error is minimized by providing a steep slaving rate gradient.

(2) Northerly Turning Error - During a turn, a pendulous MAD will tilt off the local vertical in response to the centripetal acceleration. This causes the MAD to sense a component of the earth's vertical field. Slaving cutout and low slaving rates are effective in preventing appreciable buildup of error for this case.

(3) Linear Acceleration Error - During accelerations and decelerations, as during turns, errors are induced by tilt of the pendulous MAD. Slaving cutout may again be employed to improve accuracy.

(4) Coriolis Acceleration Error - This error arises from interaction of the earth's rotation and aircraft ground speed. In the case of a helicopter flying at 100 knots at a latitude of 40 degrees, this error will be less than 0.1 degrees, and therefore can be neglected in such applications.

2. Electronic Control Amplifier Error. This unit in itself adds very little to the total system error budget. One can expect 0.1^{o} to 0.3^{o} type heading errors which result from the necessary angular conversion done within. These errors are repeatable and can for the most part be calibrated out during the compass calibration. Any residual error would be less than 0.1^{o}.

3. Magnetic Azimuth Detector Errors.

a. Assuming that the compass system is perfect and is free of acceleration errors, the user must still consider errors in application and from anomalies of the earth's magnetic field, since the compass system will reference itself to the horizontal component of the magnetic field in which it is placed.

b. Application errors occur due to the user's ability to compensate an installed system, and due to changes in the magnetic properties after installation. Compensation errors can be made small and are usually of little significance assuming that the aircraft is swung in a "clean" magnetic area by competent personnel. Installation of dc cables in the proximity of the compass transmitter can distort the earth's field. If their use is intermittent, such as for landing or signal lights, this may not be noted at the time of installation. Another problem is the addition of armament, such as rockets, installed after compensation. In short, anything which can affect the earth's field in the vicinity of the compass transmitter will affect the system accuracy.

c. The sources of magnetic heading error using a pendulous MAD can be divided into the following categories:

(1) Errors Resulting From the Effect of Accelerations (Longitudinal or Lateral) on the MAD - Since the MAD sensor is pendulously mounted, any horizontal acceleration will result in swinging of the sensor out of the horizontal plane such that it also senses a component of the vertical magnetic field. The field then sensed by the MAD is the vector sum of all fields acting within the plane of the MAD sensor. This error is obviously dependent on flight profile and magnetic heading, and very difficult to correct. The AN/ASN-43B minimizes this error by switching from the SLAVED mode to the FREE gyro mode during periods of acceleration.

(2) Errors Resulting From Distortions of the Local Horizontal Magnetic Field - Distortion of the magnetic field can be divided into one- and two-cycle errors. One-cycle error is primarily due to the permanently magnetized components of the vehicle structure. This error goes through one positive and one negative maximum in a 360-degree rotation of the vehicle. A second source of one-cycle error in the compass is due to the magnetic field generated by cables carrying dc currents near the MAD. Two-cycle error is caused by the induced magnetization of vehicle structures (soft iron) and imperfections in the electrical transmission of heading within the MAD.

(3) MAD Installation Errors - Errors that are caused by the installation of the MAD can be separated into those caused by location and those caused by orientation. Errors caused by location are the one- and two-cycle errors already discussed. The orientation errors consist of index errors and vertical orientation errors. The index error is the result of improper azimuth of the MAD relative to the longitudinal axis of the vehicle. The vertical error results because of the mechanical construction of the MAD. The MAD sensing element is suspended by a gimballing arrangement similar to a universal joint and, therefore, any unbalance of this sensing element will produce an error similar to that from horizontal acceleration previously described. Figure 1 shows what might be a typical static error curve for an uncompensated MAD. In Figure 1 the index, one-, and two-cycle errors are plotted separately, and Figure 2 the composite error curve is shown. The composite errors can be represented by the following equation:

$$\varepsilon(\psi_i) = A + B \cos\psi + C \sin\psi + D \cos(2\psi) + E \sin(2\psi) + F(\psi) + N_i$$

Where: A = Index Error

B, C = Coefficients of One-Cycle Error

D, E = Coefficients of Two-Cycle Error

$F(\psi)$ = Higher Order Cyclic Terms

N_i = Noise

ψ = Magnetic Heading

(4) A final source of heading error arises from the inability to precisely convert a magnetic heading to a true heading. True heading is required for navigation and target location functions, and is related to magnetic heading by the following equation:

True Heading = Magnetic Heading + Magnetic Variation

Therefore, the real error source here is not accurately knowing magnetic variation, which is a function of geographic location and varies with time. It is not uncommon for the magnetic variation inaccuracies to approach 0.5^{o}.

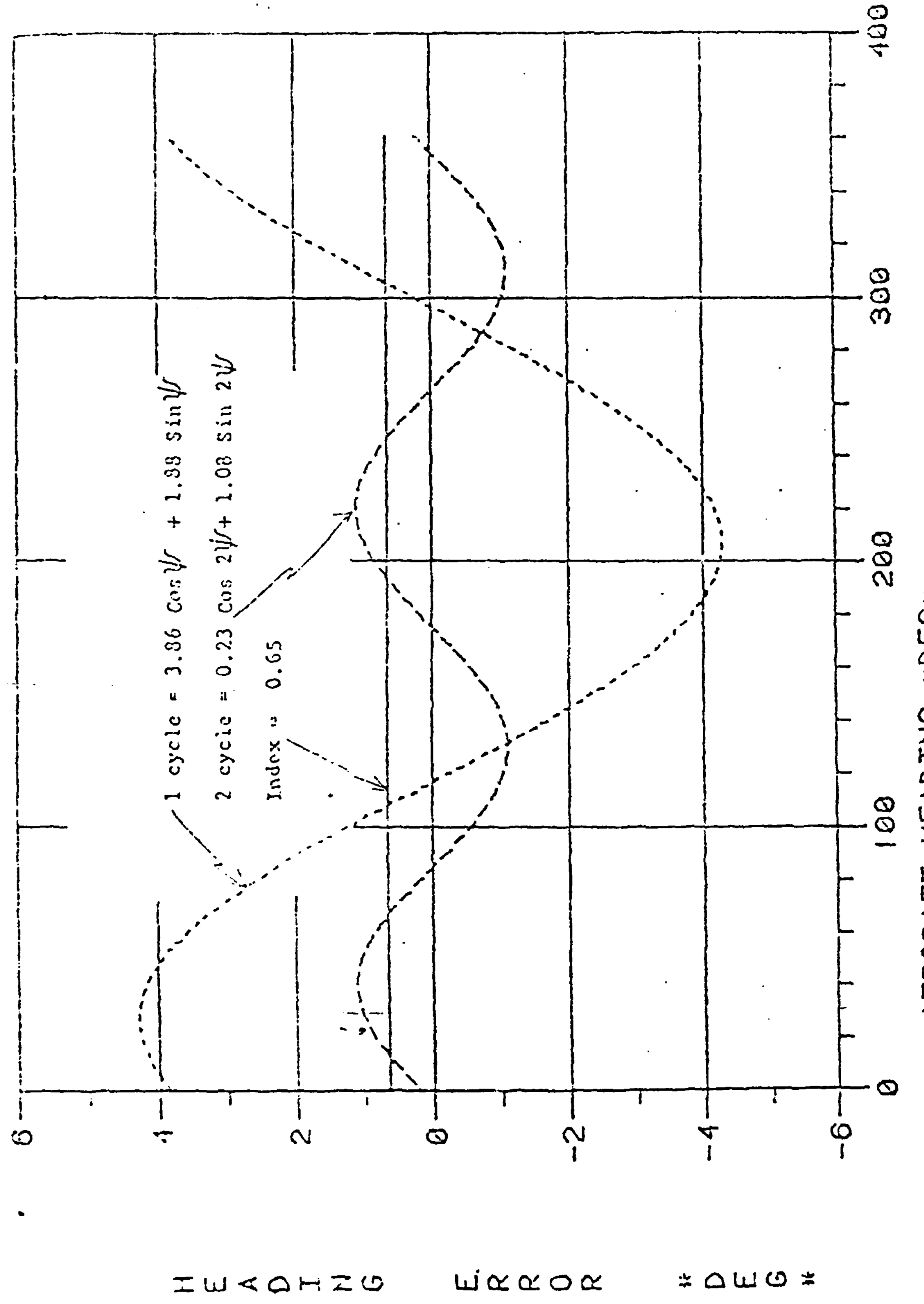


Figure 1. Magnetic deviation error components.

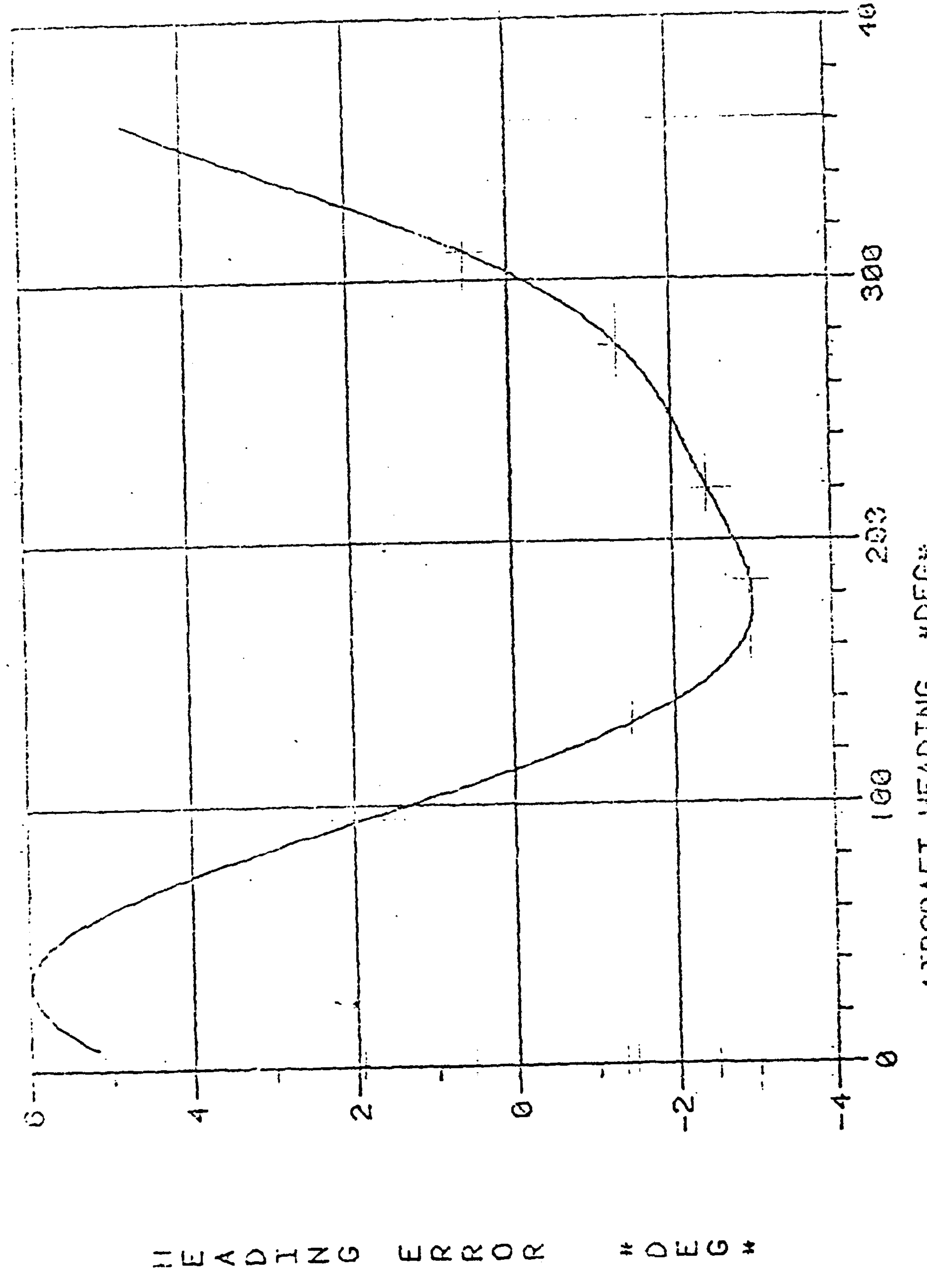


Figure 2. Composite magnetic deviation error.

APPENDIX G

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6. TOP 1-2-609, Instructional Material Adequacy Guide and Evaluation Standard (IMAGES), December 1978.

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14. TOP 7-3-507, Maintenance (Maintainability, Availability), 8 February 1971, w/Change 1, 15 March 1974.

15. See para 6 above.

16. TOP 7-3-501, Personnel Training, 15 March 1971.

17. TOP 1-2-610, Human Factors Engineering, 20 December 1977.

18. TOP 7-3-527, Internal/External Lighting (Aviation Materiel), 18 October 1978.

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20. TOP 1-1-012, Classification of Deficiencies and Shortcomings, 1 April 1979.

21. MIL-STD 882A, System Safety Program Requirements, 28 June 1977.

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23. See paragraph 4 above.

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25. See paragraph 5 above.

26. Ibid.

27. TECOM Pamphlet 70-3, R&D Acquisition Project Engineers' Handbook, 16 June 1978.

APPENDIX H

ABBREVIATIONS

TOP -	Test Operations Procedure
HRS -	heading reference system
LR -	Letter Requirements
LOA -	Letter of Agreement
ROC -	Required Operational Capability
IEP -	Independent Evaluation Plan
TDP -	Test Design Plan
TM -	Training Manual
BIIL -	basic issue item list
HFE -	human factors engineering
RAM -	Reliability, Availability, Maintainability
EIALC -	Environmental Impact Assessment Life Cycle
DG -	directional gyro
BITE -	built-in test equipment
MAD -	magnetic azimuth detector
INS -	inertial navigation system
UTM -	Universal Transverse Mercator
Cal Base -	Calibration Base
LDNS -	Lightweight Dopler Navigation System
AGL -	above ground level
Mag Var -	Magnetic Variation
NOE -	Nap-of-the-earth
RMS -	route mean square

ILMED

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