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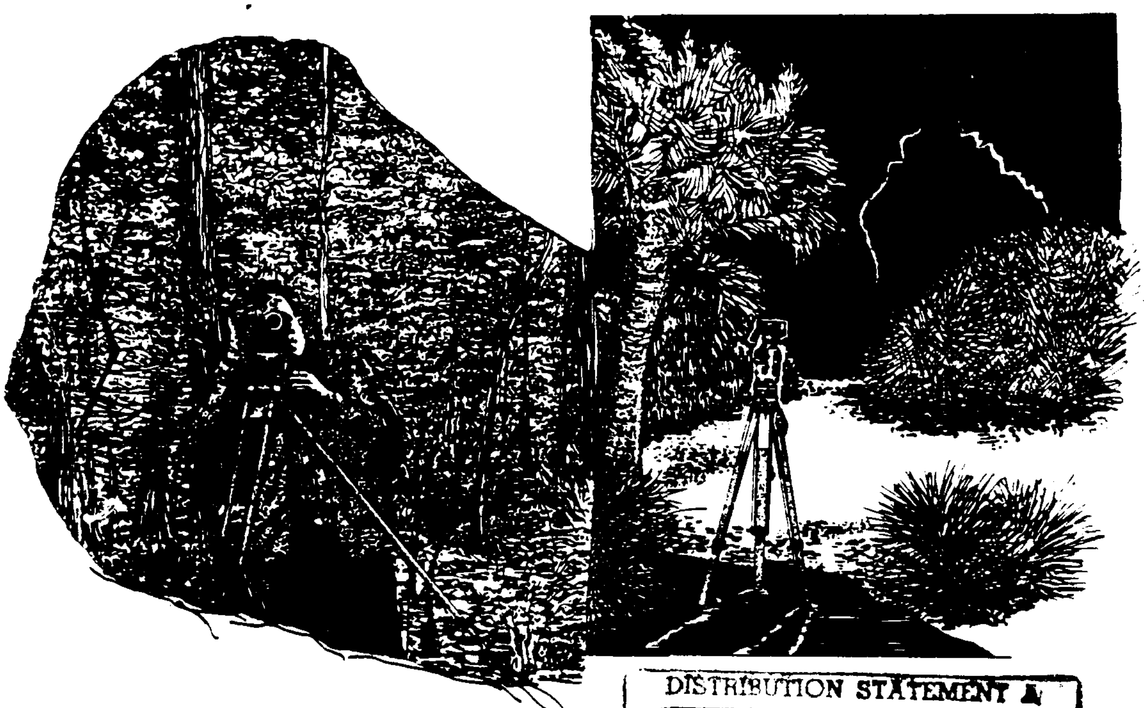
FINAL REPORT

FIELD OPERATIONAL & ENVIRONMENTAL EVALUATION OF THE AUTOMATED INTEGRATED SURVEYING INSTRUMENT (AISI)

VOLUME II OF II



APRIL 1988

COMBAT ENGINEERING DIRECTORATE
COMBAT CONSTRUCTION DIVISION
TOPOGRAPHIC EQUIPMENT

DEPARTMENT OF THE ARMY
U.S. ARMY BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER,
FORT BELVOIR, VIRGINIA 22060-5606

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FIELD OPERATIONAL AND ENVIRONMENTAL EVALUATION

(AISI)

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AUTOMATED INTEGRATED SURVEYING INSTRUMENT
(AISI)
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AUTOMATED INTEGRATED SURVEYING INSTRUMENT

(AISI)

ABSTRACT

The Automated Integrated Surveying Instrument (AISI) is a single total station concept instrument combining the usual properties of a theodolite and electronic distance measuring equipment.

Traditionally the Army's main utilization of surveying equipment has been for field artillery operations, military construction, and topographical purposes. With the advent of total station units the Army plans to conduct a series of field and laboratory tests to determine the feasibility and suitability of the new total station concept with respect to the Army's traditional role.

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

(AISI)

INTRODUCTION

The AISI is a current state-of-the-art surveying instrument being used presently by civilian construction and geodetic surveyors in the performance of their respective tasks. AISIs, in conjunction with the personal computers and special surveyors' programs developed for these computers, have increased productivity and revised surveying computational methods. Given similar military construction and geodetic surveying conducted by military personnel, in a military environment; the AISI instruments, methods and procedures should be similar or identical. With this in mind; a program to environmentally and field test three preselected AISI (total station) surveying systems, has been planned. The three surveying instruments to be evaluated are:

- Cubic Precision; Model T1A
- Geodimeter Inc.; System 440.
- Wild Heerbrugg; Model T2000

This report documents the procedures for the various AISI environmental testing, field testing, and performance demonstrations including the pass and fail criteria. Also forming part of the general test procedures are such considerations as human factors, safety, maintainability, and reliability. This report has been written in a self-contained fashion, i.e. there are no references or outside information necessary. All pertinent data, charts, graphs, or criteria are incorporated within the text.

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

(AISI)

GLOSSARY

SYMBOL	DESCRIPTION
Am	Peak acceleration magnitude
B	Bandwidth
B-A	Mean Angle
c	Collimator
C	Collimator
°C	Degrees Celsius/Centigrade
C_A	Wavelength Correction Factor Coefficient
Cm	Centimeter
COGO	Coordinate Geometry
db	Decibel
d.c.	Direct Current
D-C	Mean Angle
e	Is the number such that log e = 1
EDME	Electronic Distance Measuring Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
°F	Degrees Fahrenheit
FC	Analyser Center Frequency
Ft	Feet
Freq	Frequency
g	Gravitational Acceleration 980.6 cm/sec.^{2}, 386 in./sec.^{2}

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

(AISI)

GLOSSARY (CON'T)

SYMBOL	DESCRIPTION
G	Gauss
GHz	Gigihertz
h	Design drop weight
hr	Hour
Hg	Mercury
Hz	Hertz (Cycles/Second)
in	Inches
Kg	Kilogram
KHz	Kilohertz
Km	Kilometer
KPa	Kilo Pascals
λ	Wavelength
log	Logarithm
M, M_1, M_2, M_v	Repeatability
MHz	Megahertz
MS	Milliseconds
m	Meter
min	Minute
mm	Millimeter
mph	Miles Per Hour
mw	Microwatts

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

(AISI)

GLOSSARY (CON'T)

SYMBOL	DESCRIPTION
P	Percentage
Pa	Pascal
%	Percent
π	Pi
PSD	Power Spectral Density
R	$V_1+V_2+V_3$
R'	Analysis Sweep Rate (Linear)
R_1, R_2	Reverse pointing
RC	Analyser System Constant
RH	Relative Humidity
rms	Root Mean Square
Sec	Second
t	Circle graduation error
T	True Averaging Time
T_D	Time Duration of Am
Temp	Temperature
TF	Shock Pulse Fall Time
TR	Shock Pulse Rise Time
Type I	Degree-reading Instrument
Type II	Mil-reading Instrument
V	Mean of Residual Angles
V_1, V_2, V_3	Residual Angles

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

GENERAL REQUIREMENTS

1. GENERAL. The following are standard guidelines applicable to the AISI equipment to be laboratory tested. Unless specifically deviated from in the individual test plans, e.g., Rain Testing, these guidelines shall be observed.

2. TEST CONDITIONS. Unless otherwise specified herein or in the equipment specifications, measurements and tests shall be made at the following conditions:

a. Standard ambient. Ambient measurements and checks (e.g., pre-and post-test) are conducted at room ambient conditions as follows:

Temperature:	25°C ± 10°C (77°F ± 18°F)
Relative humidity:	Uncontrolled room ambient
Atmospheric pressure:	Site pressure

b. Controlled ambient. When the ambient conditions must be closely controlled, the following shall be maintained:

Temperature:	23°C ± 2°C (73°F ± 3.6°F)
Relative humidity:	50 percent ± 5 percent
Atmospheric pressure:	$96.45^{+66}_{-10.0}$ kPa
	(725^{+50}_{-70} mmHg)
	($28.5^{+2.0}_{-3.0}$ inHg)

3. TOLERANCES FOR TEST CONDITIONS. Unless otherwise specified, tolerances for test conditions shall be as follows:

a. Temperature. The test item shall be totally surrounded by an envelope of air (except at necessary support points). The temperature of the test section measurement system and the temperature gradient throughout this envelope, which is measured close to the test item, shall be within ± 2°C ± (3.6°F) of the test temperature and shall not exceed 1°C per meter or a maximum of 2.2°C total (equipment nonoperating).

b. Pressure. When pressure is 1.3×10^{-3} Pa or higher, it shall be measured with an accuracy of ±5 percent of the measured value.

c. Low pressure. When pressure is lower than 1.3×10^{-3} Pa, it shall be measured with an accuracy of ±10 percent of the measured value.

d. Humidity. Relative humidity at the chamber control sensor shall be ±5 percent of the measured value.

e. Acceleration. Acceleration shall be measured to within ±10 percent.

f. Time. Elasped time shall be measured with an accuracy ±1 percent.

4. ACCURACY OF TEST INSTRUMENTATION CALIBRATION. The accuracy of instruments and test equipment used to control or monitor the test parameters shall be verified prior to and following each test and then calibrated in predetermined intervals to the satisfaction of the procuring activity. All instruments and test equipment used in conducting the tests specified herein shall:

a. Be calibrated to laboratory standards whose calibration is traceable to the National Standards via primary standards.

b. Have an accuracy of at least one-third the tolerance for the variable to be measured. In the event of conflict between this accuracy and a requirement for accuracy in any one of the individual test plans the latter shall govern.

5. CALIBRATION SYSTEM REQUIREMENTS.

a. Calibration System Description. The contractor shall provide and maintain a written description of his calibration system covering measuring and test equipment and measurement standards. The portion dealing with measuring and test equipment shall prescribe calibration intervals and sources and may be maintained on the documents normally used by the contractor to define his inspection operations. The description for calibration of measurement standards shall include a listing of the applicable measurement standards, both reference and transfer, and shall provide nomenclature, identification number, calibration interval and source, and environmental conditions under which the measurement standards will be applied and calibrated. The description system and applicable procedures and reports of calibration shall be available to the Company's or Government's representative.

b. Environmental Controls. Measuring and test equipment and measurement standards shall be calibrated and utilized in an environment controlled to the extent necessary to assure continued measurements of required accuracy giving due consideration to temperature, humidity, vibration, cleanliness, and other controllable factors affecting precision measurement. When applicable, compensating corrections shall be applied to calibration results obtained in an environment which departs from standard conditions.

c. Intervals of calibration. Measuring and test equipment and measurement standards shall be calibrated at periodic intervals established on the basis of stability, purpose, and degree of usage. Intervals shall be shortened as required to assure continued accuracy as evidenced by the results of preceeding calibration and may be lengthened only when the results of previous calibrations provide definite indications that such action will not adversely affect the accuracy of the system. The contractor shall establish a recall system for the mandatory recall of standards and measuring and test equipment within established time limits or interval frequencies.

d. Calibration procedures. Written procedures shall be prepared or provided an utilized for calibration of all measuring and test equipment and measurement standards used to assure the accuracy of measurements involved in establishing product conformance. The procedures may be a compilation of published standard practices or manufacturer's written instructions and need not be rewritten to satisfy the requirements of this report. As a minimum, the procedures shall specify either the measurement standard to be used for the required accuracy of the standard and the accuracy of the instrument being calibrated. The procedure shall require that calibration be performed by comparison with higher accuracy level standards.

e. Adequacy of the calibration system. The contractor shall establish a procedure to evaluate the adequacy of the calibration system based on out-of-tolerance data generated from calibrating test and measuring equipment. The procedure shall include, but not be limited to, adjustment of calibration frequency, adequacy of the measuring or test equipment, calibration procedures and measuring or test procedures. The procedures shall specifically provide for the identification and prevention or use of any equipment which does not perform satisfactorily.

f. Notification of out of tolerance conditions. The contractor's procedure shall include the requirement for the calibration activity to notify the measurement and test equipment user or appropriate contractor element of significant out-of-tolerance conditions so that appropriate action can be taken by the contractor or test and measuring equipment user to correct possible non-conforming products. The procedure shall define what constitutes a significant out-of-tolerance condition.

g. Domestic contracts. Measuring and test equipment shall be calibrated by the contractor or a commercial facility utilizing standards whose calibration is certified as being traceable to the National Standards, has been derived from accepted values of national physical constants, or has been derived by the ratio type of self-calibration techniques. Standards requiring calibration by a higher level standards laboratory shall be calibrated by a commercial facility capable of providing the required service, a Government Laboratory under arrangements made by the contracting officer, or by the National Bureau of Standards. All standards used in the calibration system shall be supported by certificates, reports, or data sheets attesting to the date, accuracy, and environmental or other conditions under which the results furnished were obtained. All subordinate standards and measuring and test equipment shall be supported by like data when such information is essential to achieving the accuracy control required by this standard. In those cases where no data are required, a suitably annotated calibration label on the item shall be sufficient to satisfy the support data requirements of this paragraph. Certificates or reports from other than the National Bureau of Standards or Government Laboratory shall attest to the fact that the standards used in obtaining the results have been compared at planned intervals with the National Standard either directly or through a controlled system utilizing the methods outlined above. The contractor shall be responsible for assuring that the sources providing calibration services, other than the National Bureau of Standards or a Government Laboratory, are in fact capable of performing the required service to the satisfaction of this standard. All certificates and reports shall be available for inspection by authorized Government representatives.

h. Application and records. The application of the above requirements will be supported by records designed to assure that established schedules and procedures are followed to maintain the accuracy of all measuring and test equipment, and supporting standards. The records shall include an individual record of calibration or other means of control for each item of measuring and test equipment and measurement standards, providing description or identification of the item, calibration results of out-of-tolerance conditions. In addition, the individual record of any item whose accuracy must be reported via a calibration report or certificate will quote the report or certificate number for ready reference. These records shall be available for review by authorized Government personnel.

i. Calibration status. Measuring and test equipment and standards shall be labeled or some other suitable means shall be established for monitoring the equipment to assure adherence to calibration schedules. The system shall indicate date of last calibration, by whom calibrated and when the next calibration is due. The system may be automated or manual. Items which are not calibrated to their full capability or which require functional check only shall be labeled to indicate the applicable condition.

6. STABILIZATION OF TEST TEMPERATURE.

a. Test item operating. Unless otherwise specified, temperature stabilization is attained when the temperature of the operating part of the test item considered to have the longest thermal lag is changing no more than 2.0°C (3.6°F) per hour.

b. Test item nonoperating. Unless otherwise specified, temperature stabilization is attained when the temperature of the operating part of the test item considered to have the longest thermal lag reaches a temperature within test tolerances of the nominal test temperature, except that any critical component (e.g., battery electrolyte for engine starting test) will be within 1°C (1.8°F). Structural or passive members are not normally considered for stabilization purposes. When changing temperatures, for many test items, the temperature of the chamber air may be adjusted beyond the test condition limits to reduce stabilization time, provided the extended temperature does not induce response temperature in a critical component or area of the test item beyond the test temperature limits for the test item.

7. TEST SEQUENCE. Experience has shown definite advantages to performing certain tests immediately before, in combination with, or immediately following the individual testing plans or shall be defined by the Government or contractor representatives.

8 TEST CONDITIONS. Whenever practical, specific test levels, ranges, rates, and durations shall be derived from measurements made on actual or appropriately similar equipment.

9. GENERAL TEST PERFORMANCE GUIDANCE.

a. Pretest performance record. Before testing, the test item should be operated at standard ambient conditions (see 2a) to obtain and record data determining compliance with the requirements document(s) and for comparison with data obtained before, during, and after the environmental test(s). The identification & environmental test history of the specific item(s) should be documented for failure analysis purpose.

b. Pretest record. The pretest record shall include (as applicable):

(1) The functional parameters to be monitored during and after the test if not specified in the equipment specification or requirements document. This shall include acceptable functional limits (with permissible degradation) when operation of the test item is required.

(2) Evaluation criteria additional to the Failure Criteria.

10. INSTALLATION OF TEST ITEM IN TEST FACILITY. Unless otherwise specified, the test item shall be installed in the test facility in a manner that will simulate service usage, with connections made and instrumentation attached as necessary.

a. Plugs, covers, and inspection plates not used in operation, but used in servicing, shall remain in place.

b. Electrical connections normally used in service but not in test shall be provided with electrical connectors having dummy cables with protected terminations. Such mechanical connections shall also be protected.

c. For tests where temperature values are controlled, the test chamber shall be at standard ambient conditions when the test item is installed or as specified in the individual methods.

d. The test item shall be operated according to the applicable technical order or technical manual, when available, to determine that no malfunction or damage has resulted from faulty installation or handling. The requirement to operate the test item after its installation in the test facility applies only when the item is required to operate during the test.

e. Test items shall be positioned at least 15 cm (6 inches) from each other or from walls, floors, ceilings, etc., to allow for adequate circulation.

f. If the item to be tested consists of several separate units, these units may be tested separately provided the functional aspects are maintained as defined in the requirements document.

11. PERFORMANCE CHECK DURING TEST. When operation of the test item is required during the test exposure, suitable tests shall be performed to determine whether the test exposure is producting changes in performance when compared with pretest data.

12. INTERRUPTED TESTS. Unless otherwise specified in the individual methods, the following procedures and Figure 1 shall be followed when a test is interrupted. Any deviation from this guidance shall be explained in the test report.

12.1. IN-TOLERANCE INTERRUPTIONS. Interruptions during which the prescribed test tolerances are not exceeded shall be considered as part of the total test duration. (No allowance is necessary if exposure to the proper test levels was maintained.)

a. Undertest. If test tolerances have been exceeded resulting in an undertest condition, the rest may be resumed from the point at ich tolerances were exceeded following reestablishment of prescrib conditions (expect as noted in the individual test plans), and extended to ensure that the prescribed test cycle is achieved.

b. Overtest. If an overtest condition occurs, the preferable course of action is to stop the test and start over with a new test item. However, if any damage is a direct result of the overtest conditions and will not affect other test item characteristics, or if the item can be repaired, the test may be resumed and extended as in the undertest condition. If an item failure occurs during the remainder of the test, the test results shall be considered invalid.

13. HANDLING OUT-OF-TOLERANCE TEST INTERRUPTIONS. Any such interruption must be carefully analyzed. If the decision is made to continue testing from the point of interruption, to restart the last successfully completed test cycle, or to restart the entire test with the same test item, and a failure occurs, it is essential to consider the possible effects of the interruption or of the extended length of the test.

14. COMBINED TESTS. Combinations of tests may produce a more realistic representation of the effects of the environment than a series of single tests can. Combined testing is encouraged.

15. POST-TEST DATA. At the completion of each of the AISI tests, the test item shall be inspected in accordance with the equipment specifications, and the results shall be compared with the pretest data.

15.1 Post-test data shall include:

a. Complete identification of all test equipment and accessories.

b. The actual test sequence (program) used.

c. Deviation from the planned test program.

d. The room ambient test conditions recorded periodically during the test period.

e. Test item operational data.

f. A signature and data block for certification of the test data by the test engineer.

g. Other data as specified in the individual methods or equipment requirements document(s).

16. FAILURE CRITERIA. Failure of the test item to meet any one of the following conditions shall constitute a test item failure:

a. Deviation of monitored functional parameters level beyond acceptable limits established in Pre-test Performance Record or other as stipulated by the Contractor or Government representatives.

b. Nonfulfillment of safety requirements or the development of safety hazards.

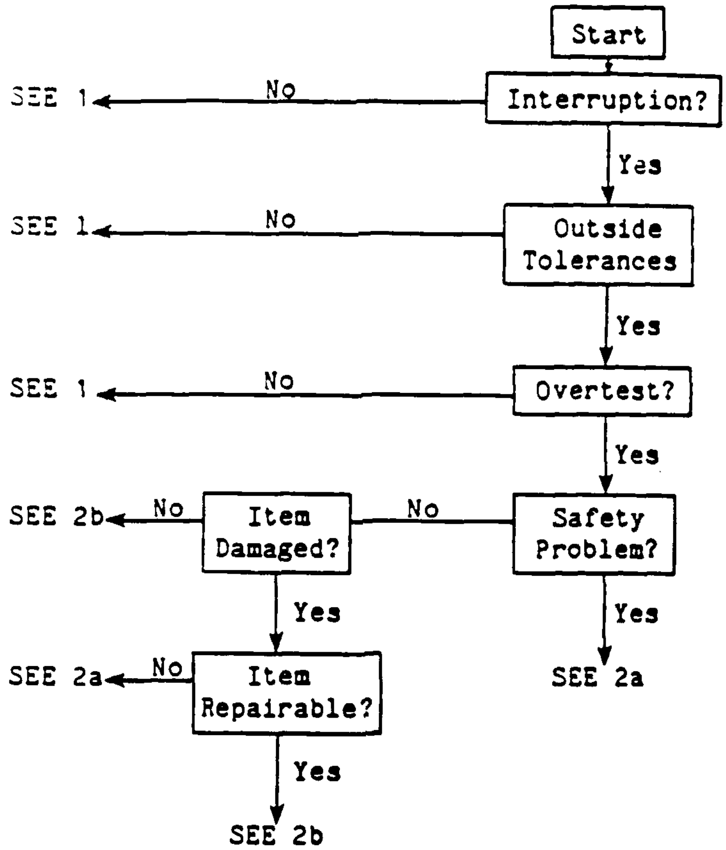
c. Nonfulfillment of specific test item requirements.

d. Changes to the test item which could prevent the equipment from meeting its intended service life or maintenance requirements. (For example: Corroded oil drain plug cannot be removed with specified tools).

e. Deviation from established environmental requirements.

f. Other.

17. ADDITIONAL OR DIFFERENT FAILURE CRITERIA. Any additional or different failure criteria shall be as specified in the equipment specification or by Government and contractor representatives.



NOTES:

1. Continue test (refer to individual test plan); extend test time if necessary.

2. Alternatives:

   a. Restart at the beginning.

   b. Complete the test with undamaged or repaired test item. (NOTE: Test results will be invalid if an item failure occurs.)

FIGURE 1. Interrupted test cycle logic.

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

(AISI)

TEST PROCEDURES INDEX

TEST PROCEDURES INDEX - Continued

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

(AISI)

TEST PROCEDURES

I. Scheduled Testing:

Each individual AISI, total station, item will follow a test schedule as listed below in Table 1.

TABLE 1

TEST SCHEDULE

SPECIFIC TESTS	
Examination	Performance/Accuracy
Accuracy	Vibration
High-temperature Operation	Performance/Accuracy
High-temperature Storage	Secure Lighting
Performance/Accuracy	Magnetic Environment
Solar Radiation	Performance/Accuracy
Performance/Accuracy	EMI
Stability	Performance/Accuracy
Humidity	Sand and Dust
Performance/Accuracy	Performance/Accuracy
Low Temperature Storage	Power Consumption
Performance/Accuracy	Battery Life
Rainfall	Human Engineering
Performance/Accuracy	Reliability
Vibration - Out of Case	Performance/Accuracy
Vibration - In Case	Maintainability
Shock	Infrared Radiation
	Safety

As indicated in Table 1 accuracy maintainability (performance) test will be conducted prior to and after each mechanical and environmental test. A determination will be made at the end of each, as to whether the performance was acceptable or not. Specific acceptability criteria are provided for during the various test procedure descriptions.

II. Test Item Preparation:

Previous to commencing the tests each AISI item will be subjected to the following checks:

A. Operational
B. Accuracy and Range
C. Distance Measurement Time

These AISI item checks, with their respective criteria for failure, are as follows:

A. Operational:

Operate and check as follows to determine operational capabilities with respect to Table 2.

Manipulate all movable parts and check:	For freedom of movement and noninterference with other parts in various operating positions throughout their maximum ranges.
Fit or attach all accessories and check:	For functionality as specified.
Check the levels:	For free movement to determine if the bubble remains within the graduations and if the bubble ends of the coincidence level remain visible.
Rotate about horizontal and vertical axes, and check the illumination system:	For uniform and steady operation.
Check microscope focus:	For uniform and clear focus around each entire circle.
Check parts, components, accessories:	For damage.

TABLE 2

OPERATIONAL FAILURE CRITERIA

Evidence that the components or accessories will not function as specified will be judged by: presence of broken, cracked, or shifted major parts or accessories; or opened joints and loosened hardware; or splintered, cracked, swollen wood on the cases; each or in combination shall constitute failure of this test.

B. Accuracy, Range, and Time:

These tests are to be conducted under stable excellent atmospheric conditions, i.e; overcast, no haze, visibility approximately 30 kilometers, and no heat shimmer. Excellent atmospheric and other conditions are described in Table 3. Prism range data are displayed in Table 4.

TABLE 3

ATMOSPHERIC CONDITIONS

	Excellent	Good	Average	Poor
Visibility	40 km 25 Miles	23.5 km 14.6 Miles	15 km 9.3 Miles	3 km 1.9 Miles
Haziness	None	None	Light	Strong
Sky	Overcast	Partially Clear	Moderate Sun	Bright Sun
Heat Shimmer	None	Minimum	Light	Severe

TABLE 4

PRISM - RANGE DATA

INSTRUMENT	NUMBER OF PRISMS	MAXIMUM RANGE - METERS ATMOSPHERIC CONDITIONS POOR	GOOD/AVERAGE	EXCELLENT
CUBIC	3	500 - 1000	2000 - 4000	4000 - 5000
	7	1000 - 2000	4000 - 6000	6000 - 7000
	10	2000 - 3000	5000 - 6000	7000
	20	———	7000	———
WILD	1	1200	2500	3500
	3	1500	3500	5000
	11	1800	5000	7000
GEODIMETER	1	TBD	2300	3000
	3	TBD	3500	5500
	8	TBD	5000	7000

Conformance to accuracy and range shall be tested previous to and as per sequence in Table 1, test schedule. It is permissible to reject one reading out of the group of 10 required for a distance measurement. More than one reject in a distance measurement shall be cause for rejecting all 10 readings and initiating a new measurement. Rejection of two consecutive distance measurements shall in any case (either reference line or baseline), constitute failure of the test. No allowance shall be made for plumbing errors in test set-ups. The accept/reject criteria herein have already provided for the maximum allowable error. It is permissible to reduce the number of retroreflecting prisms at distances less than 200 meters in order to eliminate possible off-set errors and prevent "saturating" the instrument receiver. Tests for accuracy range are described in the following set-ups:

C - Accuracy: A baseline consisting of a master monument and a 10-meter beam, graduated at each meter, respectively, with one of the meter spacings further graduated in 10 equal spacings, shall be used. The graduated beam shall be placed with the zero end at a distance of 30 meters from the master monument, then aligned radially away from the master monument. AISI equipment shall be positioned over the master monument at a height coincident (± 0.10 meter) with the retrodirective prism, mounted on the beam. Distance measurements shall then be made at 0 through 10 meters in 1-meter increments, then 0 through 1 meter, or where graduated, in 0.10-meter increments and corresponding time noted. Accuracy and corresponding time measurements not conforming to those criteria listed in Table 5 shall constitute failure of the test.

D - Range: A baseline consisting of a master monument and eight monument stations set on line 100 to 150 meters apart, at the same elevation, ± 1.0 meter, with an approximate overall length of 900 meters ± 50 meters shall be used. Horizontal baseline distances to first order accuracy shall be used. A distance measurement shall then be made to each station and corresponding time noted. A distance measurement is defined as the average series of 10 readings interrupted only by repointing at the end of the first five readings. Accuracy and corresponding time measurements not conforming to those criteria in Table 5 shall constitute failure of the test.

E - Time: A baseline consisting of a master monument and remote monument located 7 kilometers, +200 meters or -0 meters, shall be used. AISI equipment shall be positioned over the master monument, a series of three distance measurements taken, and corresponding times noted. Accuracy and corresponding time measurements not conforming to those criteria in Table 5 shall consititute failure of the test.

F - Field Procedures: The field procedures to be used as guides during the conduct of the operational field tests are outlined in Appendix V.

TABLE 5

FAILURE CRITERIA

ACCURACY, RANGE AND TIME

Accuracy and range: The instrument shall measure distances from 2 m to 7 km in excellent atmospheric conditions with a standard error not to exceed $\pm$ (5 mm + 3 PPM) after entering meteorological PPM data or correction factor when used in a system of one electro-optical package (distance meter) and one prism assembly.
Distance measurement time: After setup and actuation of the instrument's off-on power switch to the "ON" position, the time required for an initial distance reading in ambient temperatures from 120° F to -5° F shall be not more than 4 minutes. Subsequent readings shall be accomplished in not more than 6 seconds on a fixed station. The same time limitation shall apply after having been warmed from -45° F to -5° F by the winterization kit, when applicable.

III. Evaluation:

a. The AISI evaluation tests shall be performed on the Engineer Proving Ground base line in accordance with standard acceptance procedures. The collected data are to be reduced and a least squares adjustment performed. Adjustments should yield the following categories of information:

1. Combined atmospheric and instrument scale error.
2. Combined reflector and EDME constant.
3. Variance of unit weight, based on the instrument manufacturer's stated accuracy.
4. Standard error of scale error determination.
5. Standard error of EDME and reflector constant.

b. Calibration Base Line Procedures:

Observations are to be taken to a target-reflector combination, mounted on a standard tribrach. A complete set of observations consists of 10 readings to the back station.

Air temperatures are to be measured at both ends of the line being observed. The measuring devices shall be standard Army thermometers having an accuracy of ±0.1°C. The temperatures shall be measured at the beginning and end of each position. The thermometer is to be elevated at least 3 m above the ground and kept in the shade. Temperature and barometric pressure of the atmosphere shall be measure before and after each position at each end of the line. Barometric pressure is to be measured with a standard barometer having an accuracy of ±0.5 mm of mercury. The barometers are to be periodically checked with a mercury column.

c. Total Function Test:

This test is to be performed by occupying four points on a test quad. Each station shall be firmly positioned in the ground and topped by tribrach. Before occupying each station, the tribrach shall be collimated. HI, height of instrument or target, will be measured to the height above the mark of each tribrach to +0.1 mm. This height is to be measured each time the station is occupied. Next, an acceptable tribrach shall be fastened to the adjustable tribrach on the stand and carefully leveled.

The targets used shall be designed to have a retro-reflector at the center of a metal plate with one vertical and one horizontal stripe to permit sighting the center of the reflector. Two more horizontal stripes are to be placed above and below the reflector at distance corresponding to the offset between the optical axis and EDME axis of each instrument that was not made coaxial. White stripes on a black background, if chosen, make for maximum contrast and ease of pointing.

Each station of the quad is to be occupied with each instrument three times, each time with a different observer. Each observer shall measure horizontal directions using 16 plate positions (either electronic or mechanical) with direct and reverse pointings. Sixteen sets of zenith distances, or vertical angles, to be observed in circle left and circle right. Slope distances are also measure 16 times. The difference of elevation, or delta h function, is also observed and recorded. Temperature and barometric pressure, are to be measured for each set of observations. The instrument shall be shaded always by an umbrella.

d. Instrument Familiarization:

The primary rational for performing these tests by the principal operator and crew is to become familiar with the functions and characteristics of the three instruments. Because various functions differ from instrument to instrument, this initial procedure will determine any modifications required in the data collection process to accommodate a particular instrument.

e. Field Operational Checksheets:

A copy, of each of these sheets, is contained in Appendix VII.

f. Sensitivity Tests:

Prior to performing the field measurements each instrument shall be bench tested to check for level vial sensitivity, horizontal and vertical collimation error, cross hair linearity, and automatic compensator sensitivity. The purpose of these tests is to verify that the instrument is operating to the manufacturer's specifications. These tests are to be used as prequalifiers prior to field testing.

g. Automatic Compensator Sensitivity:

This test shall be performed to check the function of the instrument's automatic compensator while utilizing a Level Trier test instrument.

The Level Trier consists of a platform mounted on a beam hinged at one end and supported by a very finely threaded screw at the other end. The screw has a dial attached to it which is graduated such that on division of the dial, from the fixed index, tilts the platform 1" (arc second). Thus, the platform may be titled through an arc of several minutes very accurately and the vertical angle correction of the instrument may be conveniently checked.

The test is performed by setting the Level Trier dial to zero and carefully leveling the instrument on the platform. The telescope is aligned with the beam and the vertical angle set to 90°. Then the Level Trier is titled 10" by turning the dial and the vertical angle is recorded. This is repeated until the instrument has been titled 1' (arc minute). Then the vertical angle is changed 10° and the instrument is titled through one more minute of arc in 10" increments. Now the Level Trier is reset, the angle is changed 10°, and the sequence is repeated. The observed change in the vertical angle should correspond to the amount of tilt set into the Level Trier. The range of vertical angles to be checked is limited from 45° above the horizon to 45° below the horizon, this being considered the most commonly used range.

h. Determination of Sensitivity and Level Vial Value: The purpose of this test is to determine the sensitivity and value in arc seconds of the level vial on each of the instruments. The level tube used in surveying instruments is a glass vial with the inside ground barrel-shaped, so that a longitudinal line on its inner surface is the arc of a circle. The tube is nearly filled with a 50-50 mixture of sulfuric ether and alcohol. The remaining space is occupied by a bubble of air that takes up a location at the high point in the tube. The tube is usually graduated in both directions from the middle; thus, by observation of the ends of the bubble it may be centered, or its center brought to the midpoint of the tube.

A longitudinal line intersecting the curved inside surface of the bubble at its upper midpoint is called the "axis of the level tube." When the bubble is centered, the axis of the level tube is horizontal.

If the radius of the circle to which the inner chamber of the level tube is ground is large, a small vertical movement at one end of the tube will cause a large displacement of the bubble; if the radius is small, the displacement will be small. Thus the radius of the tube is a measure of its sensitivity. The sensitivity is generally expressed in the number of seconds of arc of the central angle, for one division marked on the tube. For most instruments the length of a division is 2 mm. The sensitivity expressed in seconds of arc is not a definite measure unless the spacing of graduations is known.

This test is performed on the Level Trier. Basically, the level bubble is moved through the range of its scale, and readings are taken simultaneously on the bubble and Level Trier micrometer. The amount which each end of the bubble moves for each new setting of the micrometer is computed, "difference, left and right." To detect irregularities in the level vial, values are computed by dividing the interval between successive micrometer readings by the number of division the bubble moves between observations. The level value for each set of observations is derived by summing successively computed values and dividing by the number of computed values. The final value is determined by summing the level values from each set of observations and dividing by the number of sets.

i. Horizontal and Vertical Collimation Check: Each instrument shall be tested for horizontal and vertical collimation errors. The instrument shall be adjusted so that there is no parallax in the telescope for the individual observer performing the test. After careful leveling a pointing is made in the direct position at the infinity target in a visual collimator. The instrument is reversed and pointed at the same target. Both horizontal angles are recorded. The procedure is repeated six times. The sum of the mean direct and reverse pointing should equal 360° 00'00". If the collimation is greater than 10", appropriate adjustments to the cross hairs are made. The test shall be reported on a test report form similar to that shown in Figure 1. A duplicate of the complete test report form shall be placed within the carrying case of the instrument to which the report applies.

Column Pointing Deg	Mil	I Mils Min D_1 Sec	II Mils Min R_1 Sec		III $\frac{D_1 + R_1}{2}$	IV Mils Min D_2 Sec	V Mils Min R_2 Sec		VI $\frac{D_2 + R_2}{2}$	VII $\angle 1$ (B−A)	VIII $\angle 2$ (D−C)	IX Δ ($\angle 1 - \angle 2$)	X Δ^2
0	0			A				C					
6	640			B				D					
6	640			A				C					
2	1280			B				D					
2	1280			A				C					
8	1920			B				D					
8	1920			A				C					
4	2560			B				D					
4	2560			A				C					
0	3200			B				D					
0	3200			A				C					
6	3840			B				D					
6	3840			A				C					
2	4480			B				D					
2	4480			A				C					
8	5120			B				D					
8	5120			A				C					
4	5760			B				D					
4	5760			A				C					
	0			B				D				$M_2^2 = \frac{\Sigma \Delta^2}{40} =$	

Column Pointing Deg	Mil	XI $\frac{\angle 1 + \angle 2}{2}$	XII V ($XI - M_1$)	XIII V^2	XIV R ($V_1 + V_2 + V_3$)	XV (t) (XIV−M)	XVI $(t)^2$	XVII $D_1 - R_1$
0	0				O			
6	640							
6	640							
2	1280							
2	1280							
8	1920							
8	1920							
4	2560							
4	2560							
0	3200							
0	3200							
6	3840							
6	3840							
2	4480							
2	4480							
8	5120							
8	5120							
4	5760							
4	5760							
	0					$\Sigma t = 0$		
M =			$\Sigma V^2 =$		$\Sigma R =$		$\Sigma C =$	
$M_1 = \frac{\Sigma m}{10} =$			$M_1' = \frac{\Sigma V^2}{9} =$		$M_v = \frac{\Sigma R}{10} =$		$C = \frac{\Sigma c}{40} =$	

$$2t^2 = M_1^2 - M_2^2$$

if $M_1^2 - M_2^2 \geq 0$

then $t = \pm\sqrt{\frac{M_1^2 - M_2^2}{2}}$

DATA SHEET FOR THEODOLITE SYSTEM TEST (HORIZONTAL)

FIGURE 1

The test shall be conducted in accordance with the following instructions which shall be printed as part of the test report form:

This test is based on a series of observations on two collimators approximately 36 degrees (640 mils) apart and on a plane having an elevation approximately the same as that of the horizontal axis of the instrument being tested. In making the following observations, each circle reading shall be estimated to the nearest tenth of a graduation of the breakdown scale. This test measures the following parameters of the theodolite:

(a) Ability of the instrument to repeat measurements
(b) Average circle graduation error
(c) Collimation error

Two sets of measurements will be made. Each set will consist of 20 angles (40 measurements) by using all sections of the horizontal circle as follows:

With the telescope in the direct position, the instrument is pointed on the left collimator with a circle reading of approximately 0 degrees and 36 minutes (5 mils). The circle is read and the seconds (mils) are recorded on line 1, column I. The angle is then turned to the right collimator, the circle read, and the seconds (mils) recorded on line 2, column I. The telescope is then reversed and pointed on the left collimator, the circle read, and the seconds (mils) recorded on line 1, column II (this will be 180 degrees (3200 mils) rather than 0 degrees (0 mils) as with the telescope direct). The angle is then turned on the right collimator, the circle read, and the seconds (mils) recorded on line 2, column II. The mean of the two readings (columns I and II) is entered on column III. Repeat this technique by changing the position of the horizontal circle to read between 36 and 72 degrees (640 - 1280 mils). Advance the circle in this fashion until all parts of the circle are covered during the test.

The second set of measurements shall be made identically and shall be recorded in columns IV and V. The mean of these readings shall be in column VI. Taking the difference between the two mean readings from column III, angle 1 shall be determined and shall be written in column VII. Likewise the difference between two mean readings from column VI shall be made and angle 2 shall be determined and written in column VIII. The difference of these two angles represents the pointing and reading error of the test (Δ). These shall be written in column IX. Column X is Δ^2. From Column X, $M_2{}^2 = \Sigma\Delta^2 \times 1/n$ shall be calculated, where n represents the total number of readings. In the case of 36 degrees, (640 mils) n = 40, therefore $M_2{}^2 = \Sigma\Delta^2 \times 1/40 \leq 4\ \text{sec}^2$ (0.0001 mil^2). Numbers for $M_2{}^2$ larger than 4 sec^2 (0.001 mil^2) indicates excessive pointing and reading error. The test setup should be checked and, after correction, two new complete sets of readings shall be made. Excessive values of $M_2{}^2$ the second time indicates that the instrument is not capable of accurately repeating readings and shall constitute failure of this test.

To check for vertical collimation, the instrument is carefully leveled and pointed at the infinity target in a visual collimator. The appropriate calculations, as above, are performed and any required adjustments made to ensure a minimum collimation error.

j. Cross Hair Linearity: This test is done to ascertain that the vertical and horizontal parts of the cross hair are truly vertical and horizontal, respectively. This check is performed by simply pointing the vertical cross hair at a well-defined point and observing that point while the telescope is moved vertically through the field of view. The same is done with the horizontal cross hair. Any observed deviation is corrected by cross hair adjustment.

k. Effective aperture: A scale graduated in millimeters shall be placed in contact with the front of the objective lens. The effective aperture is the diametrical distance of the lens. An aperture of less than 40 mm shall not be acceptable.

l. Field of view: The field of view shall be measured by pointing the telescope on a collimator or on a target not less than 300 feet (100 meters) from the theodolite. The target shall be brought to be intersection of the edge of the field and the horizontal crossline, and the horizontal circle shall be read. The target shall then be brought to the intersection of the horizontal crossline and the opposite edge of the field, and the circle shall again be read. The difference in circle readings is the field of view. The field of view in the vertical plane shall be measured as specified herein, except that the target shall be brought to the intersections of the vertical crossline and the edges of the field and the readings shall be taken from the vertical circle. Field of view shall not measure less than 1 degree 20 minutes for type I instruments or 24 mils for type II instruments.

m. Minimum focus: The telescope shall be focused on a collimator, the reticle of which has been set to simulate 7 feet (2.2 m), or the telescope shall be set at minimum focus and a graduated scale shall be moved along the line of sight until the markings are most sharply defined. The distance from this point of the scale measured along the optical axis to the vertical axis of the instrument is the minimum focus. Minimum focus shall not be more than 7 feet (2.2 m).

n. Resolution: Observations for resolution shall be made within the stadia lines, employing specially designed charts with high contrast. With the chart placed 77 feet (23.5 meters) from the telescope, (a resolution of 4 seconds, or better, of arc) the telescope shall be capable of resolving the pattern.

o. Magnification: The magnifying power, in diameters, of the telescope shall be measured by focusing the telescope for parallel light. Without change of focus, a transparent graduated scale shall be placed in front of the objective lens and as near thereto as practicable. A measuring microscope shall be focused on the image of the scale. The magnification of the telescope shall then be determined in diameters as the ratio of a given length of the scale to the length of its image in the exit pupil. When an autocollimation eyepiece is furnished, the test shall be performed in the same way. Any other method yielding values accurate within 2 percent may be used in lieu of the specified method. Evidence of a magnification for the telescope autocollimation eyepiece having a magnification less than 18 diameters is not acceptable.

p. Reticle lines:

1. Double vertical reticle lines. With the theodolite sighted on a collimator, the interval between the double vertical lines shall be measured by means of the horizontal circle. Readings differing from an apparent angle of 40 seconds, plus 5 seconds or minus 10 seconds are not acceptable.

2. Single vertical reticle line. With the theodolite sighted on a collimator, the interval between the inner edge of a double vertical reticle line and the adjacent edge of the single vertical reticle line shall be measured. The interval between the inner edge of the other double vertical reticle line and the adjacent edge of the single vertical line shall be measured in the same manner. These angles should be equal. An error of more than plus or minus 0.5 second is not acceptable.

q. Stadia lines: With the theodolite sighted on a collimator, the length of the horizontal and vertical stadia lines shall be measured by means of the horizontal and vertical circles. Any measurement less than 5 minutes or more than 7 minutes of arc is not acceptable.

The solar circle radius (r) can be calculated: $r = (64 + V^2)^{\frac{1}{2}}$. Calculated measurement differing from 15 minutes 30 seconds plus or minus 10 seconds of arc are not acceptable.

r. Automatic: The collimation error of the vertical circle with a self-indexing device shall be determined by sighting in the direct position on a mark with the horizontal crossline of the reticle, obtaining coincidence on the micrometer, and reading the circle. The operation is repeated in the reverse position. The sum of the readings should equal 360 degrees or 6400 mils. Any difference includes twice the vertical collimation error. A net error of more than 12 seconds or 0.060 mil, or failure of the device to damp within 5 seconds of time is not acceptable.

s. Optical plummet:

1. Focusing. Failure of the optical system of the plummet to produce a clear image throughout the operating range form tripod height to not less than 110 feet is not acceptable.

2. Integral with alidade. The optical plummet shall be tested for alignment with the vertical axis by viewing a target and rotating the alidade 360 degrees. Evidence that the line of sight of the optical plummet is not concentric with the vertical axis of the theodolite on all points of the circle is not acceptable.

3. On tribrach. The theodolite shall be centered over a ground marker by the plumb bob. The plumb bob shall be removed and the centering checked by means of the optical plummet. This test shall be repeated with the optical plummet over each side of the tripod head. Evidence that the line of sight is not concentric with the vertical axis is not acceptable.

t. Stadia distance: With theodilite leveled on a stand or tripod, a graduated rod set at a known distance over 100 feet from the instrument shall be sighted on. The stadia interval shall be read by means of the stadia hairs, first with the rod in the horizontal position and then in the vertical position. This interval shall be multiplied by 100. Evidence of the stadia distance being in error more than plus or minus 0.3 percent of the measured distance is not acceptable.

u. Data collection and processing system: Owing to the multiplicity of data to be accumulated in testing the AISI instruments; the observing, recording, checking, and reduction of measurements will be a lengthy process. To reduce the time involved, a data collection and processing system was developed.

The system hardware consists of a Zenith 248 MS-DOS, an IBM compatible microprocessor with a 20 megabyte hard disk, a floppy disk drive, printer, and plotter. Software types for recording measurements and processing data are commercial off-the-shelf items. This external microprocessor system will be tested to ascertain if the capabilities, as required by the Operational & Organizational Plan approved 27 September 1986, can be met. The designed external microprocessor capabilities to be substantiated are:

a. Fully MS/DOS compatible with AISI and other peripherals.

b. Direct interface with the data storage device.

c. Fully compatible modem/radio interface.

d. Direct interface to a printer and a 24 x 30 inch plotter, with a multi-pen capability for different colors and pen sizes.

e. Software package consisting of a full range of available, AISI-compatible geodetic and topographic programs.

f. Power supply 110-220 volts AC with battery backup to prevent loss of data if primary power is interrupted.

IV. Winterization Kit:

When a winterization kit is specified it shall be furnished for use with the AISI equipment for ambient temperatures below -5° F. The kit, when applicable, shall be utilized for heating up the AISI equipment previous to Accuracy, Range, and Time performance checks. Temperature and Time for heating to operating temperature shall be: from -25° F in 25 minutes, from -45° F in 45 minutes. An external four (4) hour d.c. lead-acid battery source or a military vehicle power source, via an external cable, are each acceptable.

V. Operational Temperatures:

The AISI equipment shall operate with no external assistance, without damage, from an external 12-volt d.c. power source, within the accuracies specified in Table 5, when in thermal equilibrium in air at any ambient temperature from 130° F to -5° F. The equipment shall also operate without damage and within the accuracies specified herein from 0° F to -45° F while using a winterization kit.

VI. Environmental Testing Procedures:

A performance check, which is basically the Accuracy & Range Checks, shall be made previous to and after each of the environmental tests specified in Table 1. None of the AISI equipment will be exercised during any of these test phases. It is solely the purpose of the tests from the report to qualify the equipment after its being subjected to various environmental and field deployed conditions independently.

VII. High-Temperature Operation:

AISI equipment, mounted in the operating position, with cases, battery, and all accessories shall be placed in a temperature-controlled environmental test chamber. The temperature in the chamber shall be gradually raised at the rate of 25°F per hour until the chamber temperature reaches 120°F + 5°F, -0°F. It shall be maintained at that temperature for 4 hours, then allowed to decline to normal ambient temperature. This cycle is to be repeated four times.

VIII. High-Temperature Storage:

Upon completion of High-Temperature Operation test, the AISI equipment shall be subjected to 160°F and held at that level for four hours. At the end of the 4 hour period, the temperature shall be lowered to normal ambient and the AISI equipment shall be subjected to the Performance Tests and all accessories shall be examined for damage. Evidence of damage, inability of any accessory to function properly, or nonconformance to the performance criteria shall constitute failure of this test.

IX. Performance Tests:

These tests are similar to those in paragraphs IIB, IIC, IID, and IIE.

X. Solar Radiation:

AISI equipment, mounted in the operating position, shall be stabilized in the test chamber at 110°F, and a source of directed radiant energy simulating solar radiation of not less than 335 Btu per square foot per hour shall be applied for a period of four hours. At the end of this period, the equipment will be subjected to the Performance Tests.

XI. Performance Tests:

These tests are similar to those in paragraphs IIB, IIC, IID, and IIE.

XII. Stability:

AISI equipment shall be tested for stability by aligning over one of the baselines; then with a fully charged internal battery take readings continuously until the battery is expended or the low voltage cut-off is reached as noted on the battery strength meter. Accuracy measurements not conforming to Table 5, Accuracy and Range, shall constitute failure of this test.

XIII. Humidity:

a. Place the AISI equipment with power off, mounted in the operating position, with its battery, open cases and all accessories, in a humidity chamber conforming to Appendix I. The chamber temperature shall be raised to 120°F, ±2°F; and 95 percent ±2 percent humidity applied. These conditions shall continue for not less than 24 hours at which time the temperature and humidity shall be removed and conditions allowed to stabilize for 4 hours at ambient conditions. Evidence of damage or nonconformance to Table 6, Damage Criteria, shall constitute failure of this test. AISI equipment shall be inspected also and tested as specified in Performance Tests.

TABLE 6

DAMAGE CRITERIA

Any deformation, corrosion, loosening of parts, breakage, or change of fit of any component or part, or any physical condition resulting in noncompliance of the AISI equipment with provisions of this specification.

XIV. Performance Tests:

These tests are similar to those in paragraphs IIB, IIC, IID, and IIE.

XVA. Low-Temperature Operation:

The AISI equipment will be tested as per paragraph VII, High Temperature Operation, except the temperature will be gradually lowered to -5°F +0°F -5°F for one cycle only. Performance tests similar to paragraph XVI will be performed.

XVB. Low-Temperature Storage:

Upon completion of low-temperature operational testing, the chamber temperature shall be lowered to -50°F and held for a period of not less than 6 hours. At the end of the 6-hour storage period, the chamber temperature shall be returned to laboratory conditions, allowed to stabilize and dry out for a period of not less than 24 hours at a temperature not less then 85°F. The equipment shall then be inspected for damage. Evidence of damage per criteria in Table 6 shall consistute failure of those tests.

XVI. Performance Tests:

These tests are similar to those in paragraphs IIB, IIC, IID, and IIE.

XVII. Rainfall:

AISI equipment mounted in the operating position, with its battery and with cases closed and containing accessories, shall be subjected to rain in accordance with Appendix II and the following procedure:

The wind source shall be installed and adjusted to produce a horizontal velocity of not less than 30 miles per hour. The test item shall be exposed to simulated wind-driven rainfall at a rate of 3 $\pm$1 inches per hour for not less than 5 minutes. At the end of the 5-minute exposure, install the rain covers, as applicable. The wind shall be maintained at this velocity for not less than 55 minutes. Three of the four sides of the instrument and cases shall be subjected to not less than 15 minutes of wind-driven rain, except the first side, which shall be exposed for not less than 10 minutes. The total test duration, then, is not less than 1 hour. At the end of 1 hour, the rain and wind shall be removed. The instrument, battery, and cases shall be wiped dry. The protective cover(s), when applicable, shall then be removed and the test item inspected, with particular attention to evidence of water penetration, such as free water, swelling of material or other deterioration of the instrument or cases. Evidence of damage per criteria in Table 2 and/or water penetration shall constitute failure of the test. Water found inside the equipment which is deemed to have entered during post rain inspection or during removal of covers, shall not be considered.

XVIII. Performance Tests:

These tests are similar to those in paragraphs IIB, IIC, IID, and IIE.

XIX. Vibration - AISI Equipment Out Of Case:

This vibration test shall be performed with the AISI rigidly mounted on the vibration table. The test shall be conducted in accordance with Appendix IV with the following exceptions:

a. Along each of the three major axes, fifteen minutes of cycling (fifteen 1-minute sinusoidal cycles) from 10 to 55 Hz and return, with a 0.10-inch double amplitude or maximum acceleration of 1 g, shall be performed and the major resonance noted.

b. The instrument shall be vibrated 3 minutes at 0.10-inch double amplitude, or 1 g acceleration, on the major resonant points.

c. If there are no major resonant points below 55 Hz, the instrument shall be vibrated at 55 Hz at a double amplitude of 0.10 inch, or max acceleration of 1 g, for 3 minutes.

XX. Vibration-AISI Equipment in Transport Case:

The vibration test for the equipment and accessories in the transport case(s) shall be performed with the case(s) rigidly mounted to the vibration table. The test shall be conducted in accordance with Appendix IV with the following exceptions:

One 5-minute logarithmic cycle for each of the three major axes, from 7 to 200 Hz and return, with a maximum acceleration of 1.5 g, shall be performed.

XXI. Shock:

AISI equipment stowed in transport cases, shall be shock tested in accordance with Appendix III except that the drop height shall be not less than 42 inches. There shall be one flat drop on each of the six faces, and four corner drops. Corners selected for shock shall be optional; however, two corner drops shall be sustained by the bottom shell of the case and the other two sustained by the top shall of the case. In all drops, the case shall be restrained from the secondary shock by bouncing or tumbling. At the conclusion of this shock test, the equipment shall be inspected for damage. Evidence of damaged componentry, as outlined in Table 7, of the AISI shall constitute failure of the test. The cases shall be examined. Inability of the case(s) to protect the componentry shall constitute failure of the test. Damage to cases shall be allowed provided that it does not prohibit the case from continuing its mission. Examples, of allowable damage, are as follows:

a. Superficial hairline cracks.
b. Deformation, of sealing edges less than 1/8 inch end-to-end of case, which does not inhibit action, leveling action, or sealing.
c. Wrinkling of corners which will rebound.
d. Locking latches distorted but not loose at mountings or allowing case seal to deteriorate and still able to function.
e. Handles abraded but not deformed.
f. Case abrasion but no through-the-wall rupture.

TABLE 7

For purposes of these tests damage is considered to be any deformation, corrosion, loosening of parts, breakage, or change of fit of any component or part, or any physical condition resulting in noncompliance of the AISI equipment with provisions of this report.

XXII. Performance Tests:

These tests are similar to those in paragraph IIB, IIC, IID, and IIE.

XXIII. Vibration:

A. Purpose:

Vibration testing is performed to determine the resistance of equipment to vibrational stress expected in its shipment and application environments.

B. Environmental Effects:

Vibration can cause.

1. Wire chafing.
2. Loosening of fasteners.
3. Intermittent electrical contacts.
4. Touching and shorting of electrical parts.
5. Seal deformation.
6. Component fatigue.
7. Optical misalignment.
8. Cracking and rupturing.
9. Loosening of particles or parts that may become lodged in circuits or mechanisms.
10. Excessive electrical noise.

C. Guidelines For Determining Test Procedures And Test Conditions:

1. Application. This test plan is intended for all types of military material, with exceptions, but including AISI type surveying equipment.

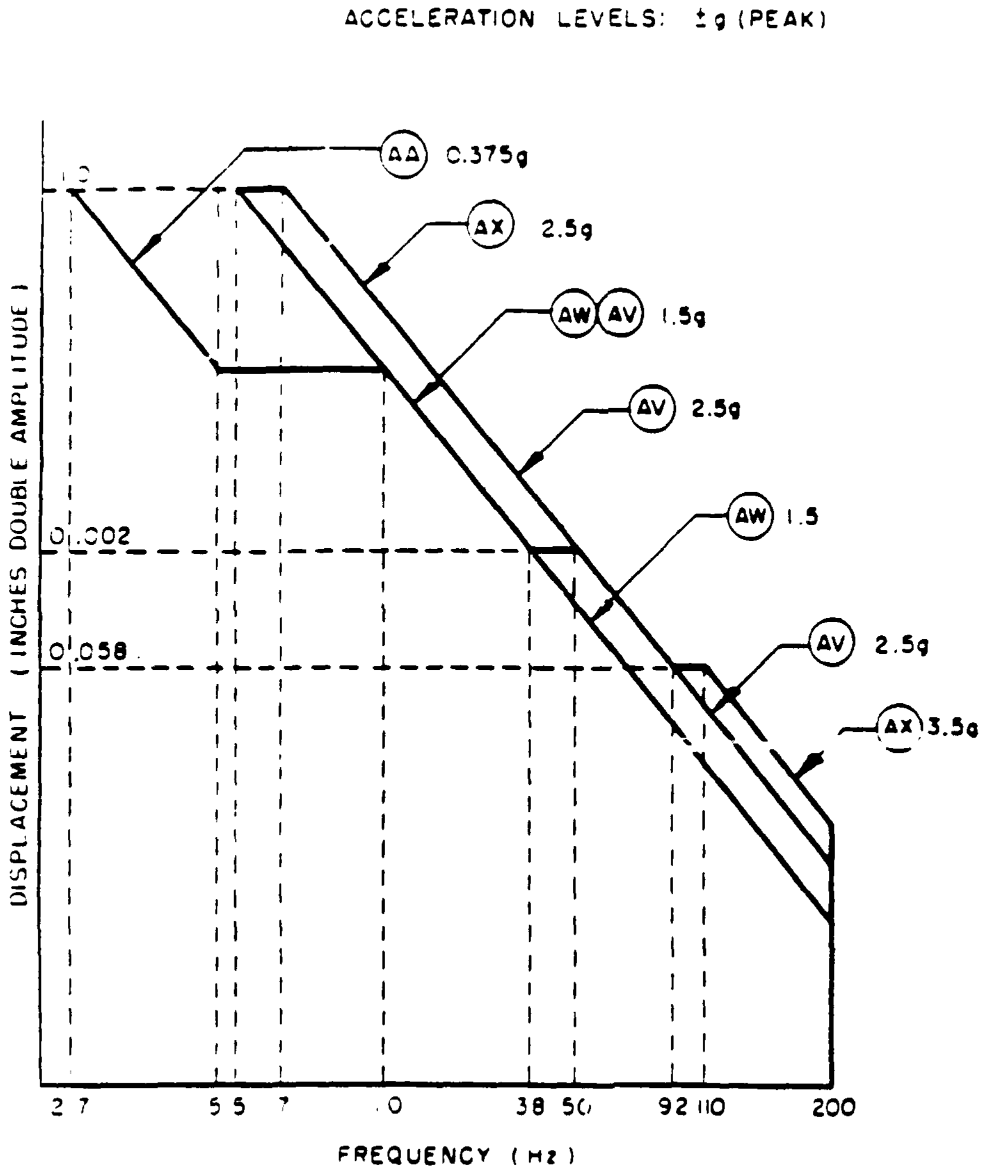
2. Sequence. Vibration testing may be performed anytime in the test program. The accumulated effects of vibration-induced stress may affect equipment performance under other environmental conditions, such as temperature, altitude, humidity, leakage or EMI/EMC. When it is desired to evaluate the cumulative environmental effects of vibration and other environments, a single test item should be exposed to all environmental conditions, with vibration testing generally performed first.

3. Test variations.

(a) Test apparatus.
(b) Test item configuration.
(c) On/off state of test item.
(d) Vibration spectrum and intensity.
(e) Duration of exposure.
(f) Axes of exposure.
(g) Location of accelerometers.

4. Choice Of Test Procedures. The choice, of test procedures, in this test plan was governed by the vibration environments to which the AISI equipment would be subjected to from the manufacturing facility, transportation to the field, and under field utilization. It is considered that the AISI equipment would be transported as secured cargo or

the category, basic transportation. Table 8, Test Procedure & Time Schedule for the Transportation of Secured Cargo, should be utilized. Specifically, transport mode; rail, air, sea, truck & semitrailer should be followed as depicted in Figure 2 curve AW. Additionally, APPENDIX IV figures as described in Paragraph 5, Basic Transportation, form part of the test procedures. The specific tests to be conducted and the necessary apparatus are also described in Appendix IV, Vibration Test Apparatus.



NOTE: ALL CURVES SHALL BE EXTENDED TO 2 Hz WHEN TEST ITEM RESONANCES BELOW 5 HZ ARE EXPECTED

VIBRATION TEST CURVES FOR EQUIPMENT TRANSPORTED AS SECURED CARGO.

Figure 2.

5. Basic Transportation. All equipment shipped as secured cargo by land, sea or air will encounter a basic transportation environment. The test levels recommended are based upon land transport stress levels because these are higher than air or sea stresses, and all air and sea transport scenarios include prior or subsequent land transport.

The land mobile environment is characterized by broadband vibration resulting from the interaction of vehicle suspension and structures with road and surface discontinuities. Representative conditions experienced in moving materiel from point of manufacture to end use are depicted in Appendix IV Figures 2 through 7 and represent real measured stresses. These stresses were created from a common carrier, and composite tactical wheeled vehicles. These conditions may be divided into two phases, common carrier transportation and mission/field transportation. Common carrier transportation is movement from the manufacturer's plant to any continental United States storage or user installation. This movement is usually accomplished by large truck and/or tractor-trailer combination. Mileage for this transportation generally ranges from 2000 to 4000 miles over improved or paved highways.

Mission/field transportation is that movement of materiel as cargo where the platform may be two wheeled trailers, 2-1/2 ton to 10-ton trucks, semitrailers, and/or tracked vehicles. Typical distances for this phase are 300 to 500 miles. Road conditions for mission/field transport differ from the common carrier in that, in addition to the paved highway, the vehicles will traverse unimproved roads and unprepared terrain (off-the-road) under combat conditions.

a. Test levels. Whenever possible, measured data should be collected on a variety of large conventional trucks, semitrailers, forklifts with shipping pallets, and conventional flatbed transport vehicles used in the common carrier environment with a realistic load configuration of 75% of the vehicle load capacities by weight. For the mission/field environment, data are required from typical tactical vehicles, to include: two wheeled trailers, 2-1/2 ton to 10-ton trucks, semitrailers, and any tracked vehicle capable of or used for transport of cargo. In as much as no AISI data exists, the vibration inputs contained in Appendix IV Figures 2 through 7 are to be utilized.

Figures 2 through 4 depict the common carrier environment. These figures are based upon data measured at the cargo floor of seven different configurations of trucks and tractor-trailer combinations. Both conventional suspensions and air-cushioned suspensions are represented. These data were collected from typical interstate highways with rough portions as part of the data base.

Figures 5 through 7 represent the cargo environment at the cargo bed of a composite of tactical wheeled vehicles, the 5-ton M813 truck and the 12-ton M127 semi-trailer. These data include differing vehicle loading conditions traversing over specially designed courses ranging from paved highway to offroad conditions at various vehicle speeds. Again the spectrum is broadband random with peaks and notches at various discrete frequency bands. Break points are provided for establishing the spectrum shape.

b. Test durations. The test duration for Basic Transportation should be based upon total miles of expected transportation. It is anticipated that the AISI Surveying Equipment will be subjected to 1000 miles of common carrier transportation as depicted in Figures 2 through 4. These vibration spectra recommended are for 60 minutes testing per 1,000 miles of transportation. Figures 5 through 7 portray the recommended vibration spectra for composite tactical wheeled vehicles: 60 minutes testing per 250 miles of transportation.

Test Procedure and Time Schedule for the
Transportation of Secured Cargo.

Table 8

Transport Mode	Figure Curve 4/	Applicable Test	Sweep Time 3/
Rail, air, sea, truck or semitrailer 1/	AW	Sinusoidal Cycling for 84 minutes Per Axis	12 minutes 5-200-5 HZ
Any of above plus tracked vehicle 2/	AV	Sinusoidal Cycling for 84 minutes Per Axis	12 minutes 5-200-5 HZ
Any of above plus 2-wheeled trailer 2/	AX	Sinusoidal Cycling for 84 minutes Per Axis	12 minutes 5-200-5 HZ

1/ The normal transport of items as secured cargo, with land transport over paved roadways.

2/ The transport of items as secured cargo to include land transport over paved roads, unimproved roads and cross-country terrain.

3/ Sweep time may be 15 minutes if test requirements go to 2 HZ.

4/ For vibration isolated items, curve AA is to be used in the lower frequency range (below 13 HZ) and the curve appropriate to the mode of transportation for the higher frequencies.

XXIV. Performance Tests:

These tests are similar to those in paragraph IIB, IIC, IID, and IIE.

XXV. Secure Lighting:

The AISI equipment will be tested to ensure that all external lighting conforms as follows: The AISI instrument panel shall have internally mounted illumination for night operation with panel dials, knobs and switches which shall be functionally grouped and constructed for simple operation. The front panel shall consist of not less than the following functions:

a. Off-on.
b. Battery strength.
c. Self-check.
d. External signal return.
e. Measurement actuator.
f. Slope distance display.
g. Illumination for control panel.
h. Tracking mode.

Ninety five (95) percent of all external lighting energy, emitted between 300 and 1100 nanometers, shall be a blue-green color between 400-700 nanometer wave lengths. No light shall be visible beyond a 50 meter circle with the AISI instrument as center point under moonless & starless night conditions. All external visible light produced shall be intensity adjustable & shall not exceed current level footlambert intensity.

XXVI. Magnetic Environment:

The AISI electronics shall be positioned over a point from which a baseline distance has been established. As magnetic source shall be positioned to produce a magnetic field of not less than 3 gauss (G) at the instrument. Ten distance readings shall be made with the lines of magnetic force directed in each of the following directions: North-south, east-west, and vertical. Readings and corresponding times not conforming to Table 5 accuracy and range and distance measurement time shall constitute failure of the test.

XXVII. Performance Tests:

These tests are similar to those in paragraph IIB, IIC, IID, and IIE.

XXVIII. Electromagnetic Interference (EMI):

The AISI instruments shall be placed 30 inches ± 2 inches above the facility floor. No external ground shall be attached. The instrument's external power source with external power cable (battery pack) shall be positioned on the stand beside the instrument during the radiated test. Antenna equipment shall be oriented at 1 meter test distance from the AISI instrument with all emissions being measured from one position. During radiation tests, no point of the antennas shall be less than 1 meter to the walls & 0.5 meters to the ceiling of the shielded enclosure or obstruction.

The broadband & narrowband emission limits are shown in Figures 3 & 4, respectively. The electromagnetic interference emission frequency spectrum scan shall be from 0.014 through 1 GHz during the radiated tests with the following exceptions: (a) broadband radiated emissions at 0.3 MHz and 0.7 MHz shall be increased 5 db and, (b) broadband radiated emissions at 150 MHz shall be increased 6 db above the requirements of Figure 3.

Nonconformance to the limits set by either Figure 3 or Figure 4 shall constitute failure of this test.

XXIX. Performance Tests:

These tests are similar to those in paragraphs IIB, IIC, IID, and IIE.

XXX. Sand & Dust:

The AISI equipment, not in its transport case, without its lens cover, and the closed transport case shall be placed in sand and dust testing chamber not less than 36 inches high, 36 inches wide, and 36 inches deep. Sand and dust of 140 mesh silica flour shall pass through the chamber at a velocity of 100 to 500 feet per minute. The density of sand and dust shall be maintained at 0.1 to 0.5 gram per cubic foot within the test area. The internal temperature shall be maintained at 77°F $\pm$ 5°F. The relative humidity shall not exceed 30 percent. The AISI equipment shall be subjected to this test for a period of 15 minutes. Nonconformance to the following shall constitute failure of this test: After being subject to the sand & dust test the AISI equipment & transport case shall show no evidence of sand and dust penetration into the optics of electronics package, or any lens abrasion. The transport case shall no evidence of sand or dust penetration.

XXXI. Performance Tests:

These tests are similar to those in paragraphs IIB, IIC, IID, and IIE.

XXXII. A. Power Consumption:

While the AISI equipment is being utilized in its normal functions, the power required shall be monitored continuously. Any power consumption in excess of that specified in power (see below) shall constitute failure of this test.

B. Power:

AISI equipment shall operate from an internal 12-volt dc NiCad battery or from an external lead-acid 12-volt dc battery via the external power cable. AISI equipment shall contain built-in protection against reverse polarity from each power source. Winterization kit heating elements shall be operable from either 12-volt dc batteries.

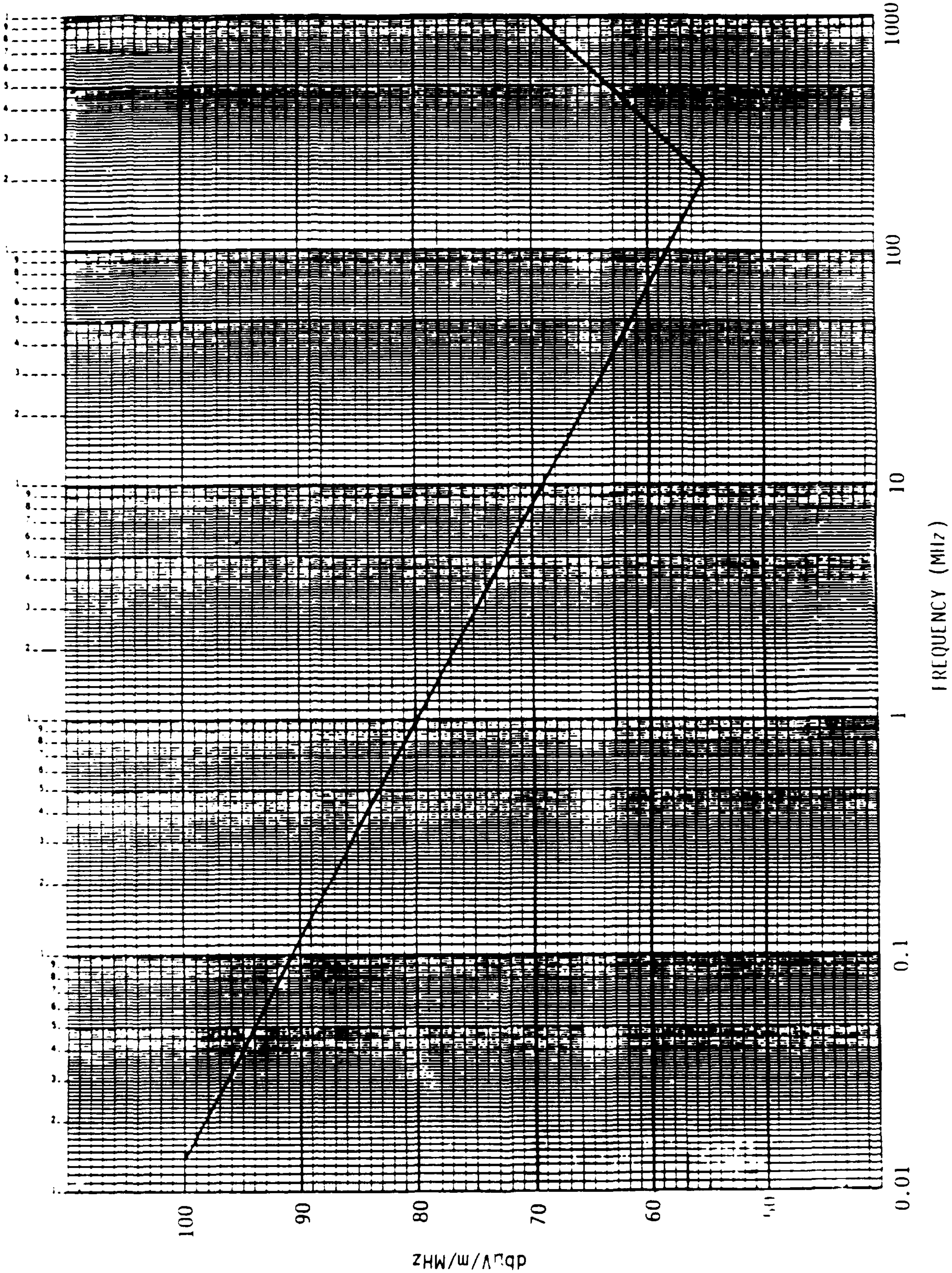


FIGURE 3. BROADBAND EMISSIONS LIMITS

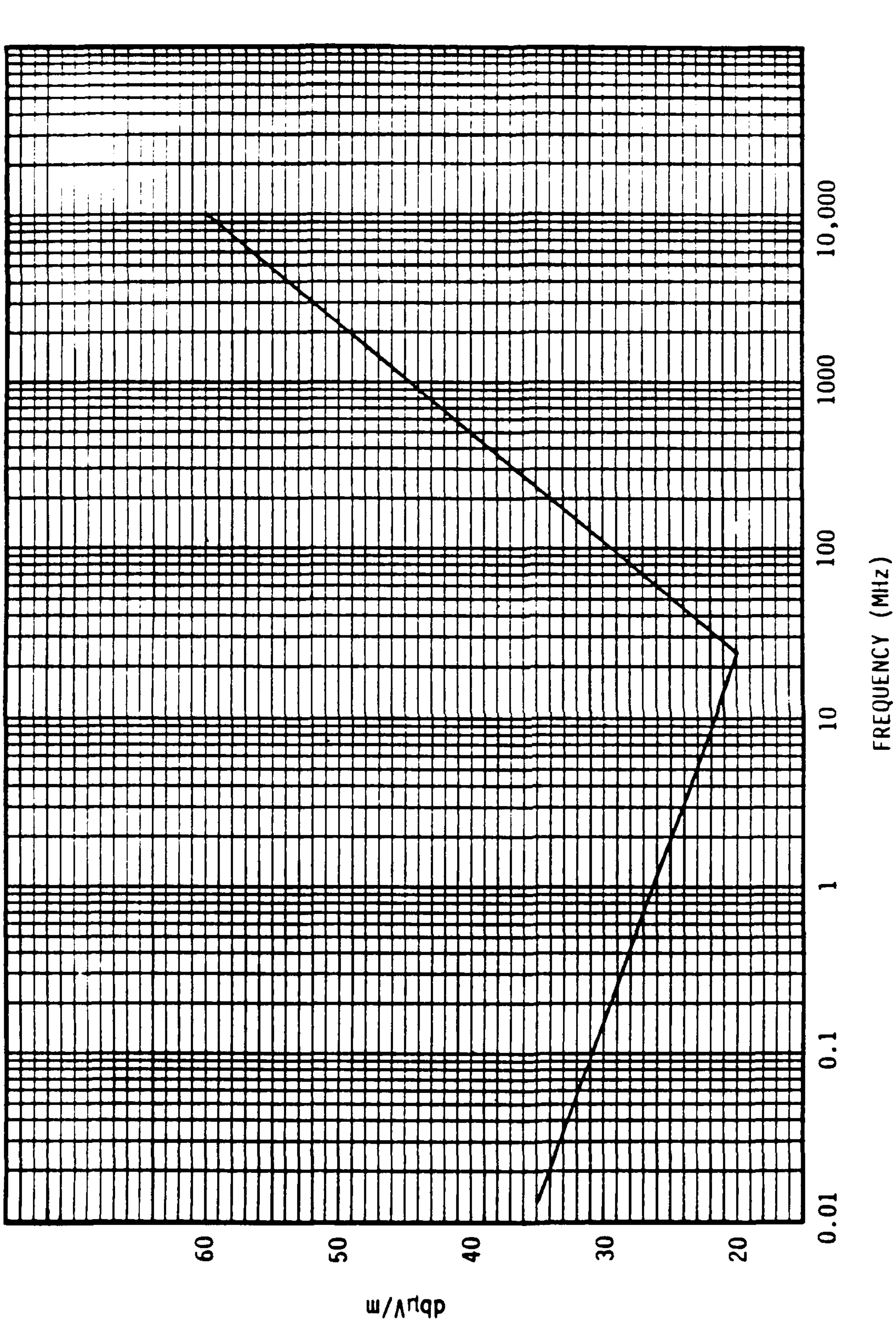


FIGURE 4. NARROWBAND EMISSIONS LIMITS

XXXIII. Battery Life:

Main power: AISI equipment shall be set up on a baseline used in accuracy, ± 5mm + 3 PPM. Measure the distance, using the main power source (NiCad battery), until the power is insufficient for operation or the measurements are not in compliance with ± 5mm + 3 PPM accuracy and range. The total operating time shall be determined and nonconformance to main power source shall constitute failure of this test.

External power source: The AISI equipment shall be set up on a baseline used in accuracy, measure the distance using the lead acid battery external power source. Nonconformance to accuracy, of ± 5mm + 3 PPM shall constitute failure of this test.

Main power source: AISI shall be provided with a nickel-cadmium battery or battery pack with a combination of cells to give 12-volt operation. The battery shall be an internal or external power source. The battery shall be rechargeable via a 110/120 volt, 50/60 Hz charger supplied with the system and shall provide at least one hour of measuring time at 68°F (20° C). The charger will include an adapter for connection to 220 volt power suppliers in Europe. The battery(s) shall be spillproof and shall have no detectable liquid or gas regardless of operation or storage orientation and shall not be damaged when subjected to shock testing as specified in Shock, Para XXI. The battery shall not be damaged nor lose capacity when charged continuously from the charger supplied with the system.

XXXIV. Human Engineering:

In the course of testing the AISI equipment it shall be tested for considertion given to field/soldier applicable human engineering factors. During the course of all testing herein, test directors shall scrutinize the equipment to determine hardware compatibility to required operator functions. The following functions shall be noted specifically.

a. Suitability for backpack.
b. Operation using arctic mittens.
c. Ease of sighting, tangent running, and clamping.
d. Adaptability to night operation.
e. Location and configuration of all controls.
f. Compatibility of operation with other surveying hardware.
g. Adaptability to charging battery.
h. Interchangeability of AISI componentry with other hardware during operation.
i. Adaptability to easy "setup" in field operation.
j. Hardware presents no safety hazard from electronics, optics, or mechanical hazard to operator, maintenance personnel, and others.
k. Operation using chemical/biological protective clothing.

Consideration should be given also to other factors of field applicable utilization and possible improvements in design.

XXXV. Reliability:

The AISI equipment shall be tested for reliability as follows: The specified Mean-Time-Between-Failure (MTBF) of the AISI shall be 20 missions for the system and 300 hours for the continuous Electronic Cycling.

The reliability test mission shall consist of 10 cycles of the following profile:

a. Start with AISI equipment packed for transport.
b. Unpack and set up for operation over a known baseline.
c. Perform 10 readings.
d. Dismantle AISI equipment and repack for transport.
e. Perform manual transport function for not less than 5 feet and return to original position.

NOTE: The use of a pedestal in lieu of a tripod on the baseline is allowed to minimize operator errors in plumbing.

Power for the reliability test shall be either internal volts dc or external power from a 12 volt military battery. The use of two batteries to complete the reliability test is allowable. For the purpose of this test, a mission reliability failure shall be defined as any malfunction, degradation of performance outside specified limits, or personnel and equipment safety hazard which requires more than 30 minutes total operator maintenance time (active and waiting clock time) to correct in order to continue with the defined mission. Repetitive malfunctions occuring more than two times, though corrective within 30 minutes, shall be considered a mission reliability failure. Once the mission is interrupted for more than 30 minutes, it is stopped and counted as a failure. Malfunctions attributable to operator error shall not be considered as chargeable reliability failures. Continue testing until either an "accept" or "reject" decision is reached. The accept/reject decision for the AISI mission reliability test shall be based on 20 missions with three failures being cause for rejection of the the instruments.

Electronic Cycling Test: For the Electronics Cycling Test portion, two instruments shall be placed in an environmental chamber in the operational mode. The chamber temperature shall be set and remain at 55°F for the duration of this test. Power to the instruments shall be supplied by an external source. Measurements shall be initiated an continued for the duration of this test with the following exceptions:

(1) The instruments shall be cycled through "self-check" twice each minute.

(2) The instruments shall be turned off (using the instrument switch) for period of 30 ± 5 seconds once in each ten minute period. This procedure shall continue 24 hours each day for an uninterrupted seven day period. Automatic cycles are allowable for the test. At the end of the seven day period the instrument shall be removed from the chamber and tested in accordance with performance test, para XXXVI. Only active operating time shall count toward the seven day test period.

Inability of an instrument to perform any of the operational functions either in the chamber or during operational testing shall constitute failure of this test. Two failures within the seven day time span of this test shall constitute failure of this test. Two successive failures of the Electronic Cycling Sequence shall consititute failure of this test.

XXXVI. Performance Tests:

These tests are similar to those in paragraph IIB, IIC, IID, and IIE.

XXXVII. Maintainability:

Maintenance support evaluation. Maintenance operation required during first article testing shall be accomplished to determine conformance to the following.

Maintainability.

Maintenance support. Assemblages or support elements such as technical manuals, repair parts, special tools, and test equipment outlined in Data Requirements and Provisioning shall be adequate to perform the intended function of assisting or conducting maintenance operations during testing as specified in Table 1.

Data requirements. The contracting officer should include requirements for such data as technical publications, instructional materials, illustrated parts lists, early delivery of AISI systems of training development, and contractor's maintenance and operational manual to be furnished with each instrument.

Provisioning. The contracting officer should include provisioning requirements for repair parts and maintenance tools as necessary (including any special tools) and instructions on shipment of instruments.

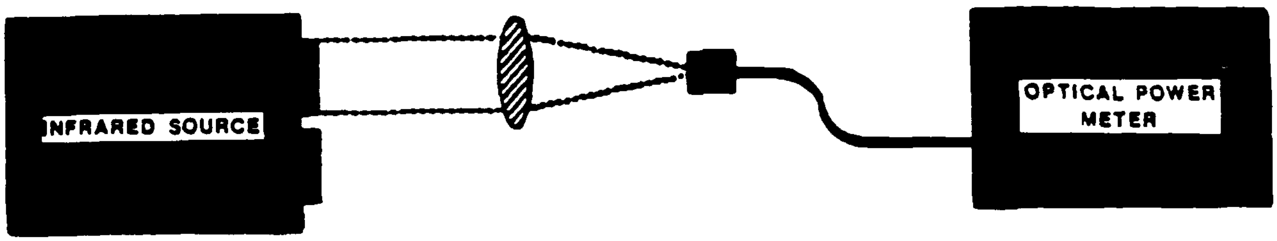
Maintenance ratio. AISI shall have a maintenance ratio of not more than 0.05 when tested as specified in performance paragraph II, A, B, C, D and E. Maintenance ratio is defined as the ratio of the total active maintenance man-hours required (scheduled and unscheduled) to the total operating time. Operating time to perform each mission and the active maintenance man-hours required for both scheduled and unscheduled maintenance shall be recorded. Man-hour for repair of replaced components and scheduled before-and-after operation checks are excluded. A maintenance schedule shall be furnished prior to the start of any testing.

Ease of maintenance. AISI construction shall provide ease of access to batteries and fuses (or reset buttons) such that tools are not required to connect a battery or external power nor to change a fuse. AISI construction shall provide a self-test display to verify satisfactory operation capability prior to initial distance measurement.

Failure of the support elements to maintain the AISI shall constitute failure of this test. Errors or inadequacies in the manuals shall not be considered in assessing the maintenance support.

XXXVIII. Infrared Radiation Testing & Verification:

Infrared Radiation Testing & Verification: The Contracting Officer has received and evaluated contractor furnished infrared irradiance and power test data for each of the AISI systems. The test configuration utilized was as depicted in the figure below:



TEST SETUP FOR TOTAL POWER MEASUREMENT

LENS MUST COLLECT TOTAL BEAM AND FOCUS TO SPOT NO LARGER THAN DETECTOR

After evaluation and comparison with applicable government requirements each, of the submitted data, was determined to be in compliance. An AISI pertinent illustrative computational example is submitted in Appendix VI. Two parameters recognized for safe irradiance levels are: infrared tube power less than the allowable maximum power; and margin of safety on irradiance of one (1) or greater. Both of these are established in Appendix VI.

XXXIX. Safety:

Safety: As a result of the information and facts presented in paragraph XXXVIII and the AISI Safety Assessment Report of March 1987 the AISI systems have been determined to contain no uncontrolled hazards to operators, bystanders, or maintenance personnel.

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(AISI)

GENERAL APPENDIX

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APPENDIX I

HUMIDITY TESTING

1. TEST FACILITY.

a. The required apparatus shall consist of a chamber or cabinet, and auxiliary instrumentation capable of maintaining and continuously monitoring the required conditions of temperature, and relative humidity throughout an envelope of air surrounding the test item(s). See General Requirements.

b. Unless specified otherwise, the test volume of the chamber or cabinet and the accessories contained therein shall be constructed and arranged in such a manner as to prevent condensate from dripping on the test item(s). The test volume shall be vented to the atmosphere to prevent the buildup of total pressure and prevent contamination from entering. Relative humidity shall be determined by employing either solid-state sensors whose calibration is not affected by water condensation or by an equivalent method, such as fast-reacting wet-bulb/dry-bulb sensors or dewpoint indicators. Sensors that are sensitive to condensation, such as the lithium chloride type, are not recommended for tests with high relative humidity levels. A data collection system separate from the chamber controllers shall be employed to measure test volume conditions. A recording device shall be mandatory for the data collection system. If charts are used, the charts shall be readable to within $\pm 0.6°C$. If the wet-wick control method is approved for use, the wet bulb and tank shall be cleaned and a new wick installed before each test and at least every 30 days. Water used in wet-wick systems shall be of the same quality as that used to produce the humidity. Water bottle, wick, sensor, and other components making up relative humidity measuring system shall be visually examined at least once every 24 hours during the test. The velocity of air flowing across the wet-bulb sensor shall be not less than 4.5 meters per second (900 feet per minute), and the wet wick shall be on the inlet side of the fan to eliminate the effect of fan heat. The flow of air anywhere within the envelope of air surrounding the test item shall be maintained between 0.5 and 2 meters per second (98 to 394 ft/min).

c. Relative humidity within the envelope of air surrounding the test item shall be created by steam or water injection. Water used in either method shall be distilled, demineralized, or deionized and have a resistance of not less than 500,000 ohms. Its quality shall be determined at periodic intervals (not to exceed 15 days) to assure its acceptance. If water injection is used to humidify the envelope of air, the water shall be temperature conditioned before its injection to prevent upset of the test conditions and shall not be injected directly into the test section. Condensation developed within the chamber test volume during the test, shall be drained from the test volume and discarded.

d. No material other than water shall be brought into physical contact with the test items that will cause the test items to deteriorate or that will affect the test results. No rust or corrosive contaminants or any material other than water shall be introduced into the chamber test volume.

e. Dehumidification, humidification, heating, and cooling of the air envelope surrounding the test item shall be achieved by methods that do not change the chemical composition of the air, water, or water vapor within that volume of air.

2. CONTROLS.

a. Test parameters. Unless otherwise specified in the requirements documents, temperature and relative humidity measurements made during the test shall be continuous if measurements are in analog form, or at intervals of 15 minutes or less if measurements are in digital form.

b. All instrumentation used with the selected test chamber shall be capable of meeting the accuracies, tolerances, etc., as stated in Rain Testing, Paragraph 10, Tolerances for Test Conditions.

3. TEST INTERRUPTION.

a. Undertest interruptions. An undertest interruption may be best handled by keeping the chamber closed in an effort to maintain tolerances. As long as the tolerances are maintained, testing may be resumed by reestablishing the prescribed conditions and continuing from the point of the interruption. If an unscheduled interruption occurs that causes the test conditions to exceed the allowable tolerances toward standard ambient temperatures, the test must be reinitiated at the end of the last successfully completed cycle. Any test item failure that occurs shall be treated as a failure.

b. Overtest interruptions. An interruption that results in exposure of the test item to conditions more extreme than required by the requirements documents should be followed by a complete physical examination and operational check of the test item (where possible) before any continuation of testing. This is especially true where a safety problem could exist, such as with munitions. If a problem is discovered, the preferable course of action is to terminate the test and reinitiate testing with a new test item. If this is not done and test item failure occurs during the remainder of the test, the test results may be considered invalid. If no problem has been encountered, reestablish preinterruption conditions and continue from the point where the test tolerances were exceeded.

4. PREPARATION FOR TEST.

a. Preliminary steps. Before initiating any testing, the test chamber should be operated and its proper operation verified before the actual test is begun.

b. Pretest standard ambient checkout. All items require a pretest checkout at controlled ambient conditions to provide baseline data. For this pretest procedure, checkout should be conducted before Step 1. Conduct the pretest checkout as follows:

Step 1. Insert the test item into the test chamber.

Step 2. Prepare the test item in its required operational configuration in accordance with Installation of Test Item in Test Facility; Appendix II, Paragraph 7.

Step 3. Adjust the chamber to controlled ambient conditions and maintain for 24 hours.

Step 4. Conduct a complete visual examination of the test item.

Step 5. Document the results.

Step 6. Conduct an operational checkout.

Step 7. Record results for compliance with Pretest Performance Requirements.

5. PROCEDURES.

The following test procedures are so structured as to provide the necessary information concerning the test item in a warm-humid environment.

Step 1. With the test item in the chamber in its operational configuration, adjust the chamber conditions to those given in Table 1 for the time, 0000, of the cycle.

Step 2. Perform a 24-hour cycle with the time-temperature-humidity values specified in the appropriate cycle or the approximated curves of Figure 1.

Step 3. Perform an operational checkout of the test item at any convenient time in the 24-hour cycle during which test conditions are constant and at maximum temperature and RH levels. Operational checks should be conducted at least once every five cycles.

Step 4. Repeat Steps 2 and 3 for Normal Test Duration Cycle-3 (45 cycles) as indicated on Table II.

Step 5. Adjust the chamber to controlled ambient conditions and maintain for at least 24 hours.

Step 6. Conduct a complete visual examination of the test items.

Step 7. Document the results as per Information To Be Recorded, Paragraph 6.

Step 8. Conduct an operational checkout of the test items.

Step 9. Document the results as in Step 7.

Step 10. Compare these data with the pretest data.

6. INFORMATION TO BE RECORDED.

a. Previous test methods to which the test item has been subjected.

b. Results of each performance check (pre-, during, and post-test) and visual examination (and photographs, if applicable).

c. Length of time required for each performance check.

d. Procedure and test levels used.

e. Exposure durations.

f. Time versus temperature and humidity.

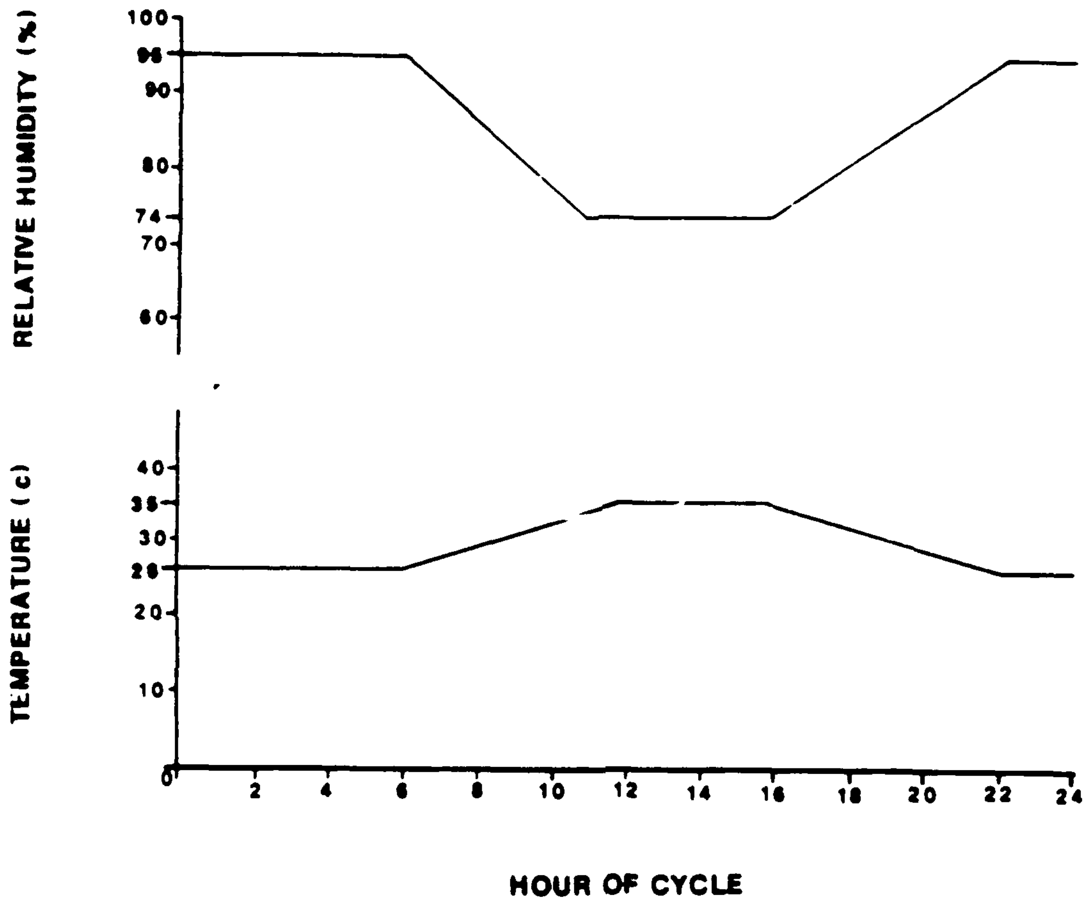
TABLE I

High-humidity diurnal categories 1/

Time	Natural High Humidity Cyclical Temp °F	°C	RH %
0000	80	27	100 2/
0100	80	27	100
0200	79	26	100
0300	79	26	100
0400	79	26	100
0500	78	26	100
0600	78	26	100
0700	81	27	94
0800	84	29	88
0900	87	31	82
1000	89	32	79
1100	92	33	77
1200	94	34	75
1300	94	34	74
1400	95	35	74
1500	95	35	74
1600	93	34	76
1700	92	33	79
1800	90	32	82
1900	88	31	81
2000	85	29	91
2100	83	28	95
2200	82	28	96
2300	81	27	100

1/ Temperature and humidity values are for ambient air.

2/ For chamber control purposes, 100% RH implies as close to 100% as possible, but not less than 95%.



Natural temperature-humidity cycle

FIGURE 1

TABLE II. Test cycles (days).

	NATURAL			INDUCED	
Hazardous Items	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Normal Test Duration1/	20	120	90	30	30
Quick Look1/	7	15	12	7	7
Non-Hazardous Items					
Normal Test Duration1/	10	60	45	15	15
Quick Look1/	5	15	12	7	7

1/ Operational checks are required at least once every 5 days, but more frequent checks are recommended for early detection of potential problems.

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

APPENDIX II

RAIN TESTING

1. PURPOSE. The rain test is conducted to determine the following:

a. The effectiveness of protective covers or cases in preventing the penetration of rain.

b. The capability of the test item to satisfy its performance requirements during and after exposure to rain.

c. The physical deterioration of the test item caused by the rain.

2. ENVIRONMENTAL EFFECTS. Rain (when falling, upon impact, and as deposited water) has a variety of effects on materiel.

a. In the atmosphere, it:

(1) Interferes with or degrades radio communication.

(2) Limits radar effectiveness.

(3) Degrades or negates optical surveillance.

(4) Decreases effectiveness of personnel in exposed activities.

(5) Inhibits visibility through optical devices.

b. On impact, it erodes surfaces.

c. After deposition, it:

(1) Degrades the strength of some materials.

(2) Promotes corrosion of metals.

(3) Deteriorates surface coatings.

(4) Can render electrical or electronic apparatus inoperative or dangerous.

d. After penetration into containers, it:

(1) Causes malfunction of electrical equipment.

(2) May freeze inside equipment, which may cause delayed deterioration and malfunction by swelling or cracking of parts.

(3) Causes high humidity which can, in time, encourage corrosion and fungal growth.

3. SPECIAL CONSIDERATIONS.

a. Operational requirements. The failure of the test item to satisfy the requirements of the equipment specification must be analyzed carefully and related information must be considered, such as:

(1) Degradation allowed in the performance characteristics because of rainfall exposure.

(2) Necessity for special kits for special operating procedures.

(3) Safety of operation.

b. Water penetration. Based on the individual test item and the requirements for its nonexposure to water, determine if one of the following is applicable:

(1) Unconditional failure. Any evidence of water penetration into the test item enclosure following the rain test shall be considered a failure.

(2) Acceptable water penetration. Water penetration of not more than 4 cm^3 per 28,000 cm^3 (1 ft^3) of test item enclosure shall be acceptable, provided the following conditions are met:

(a) There is no immediate effect of the water on the operation of the test item.

(b) The test item in its operational configuration (transit/storage case open or removed) shall successfully complete the induced temperature/humidity procedure as described in Appendix I, Humidity Test.

c. Differential Temperature. Experience has shown that a temperature differential between the test item and the rainwater can affect the outcome (leakage) of a rain test. It is recommended that whenever possible, the test item temperature be at least 10°C (18°F) higher than the rain temperature at the beginning of each 30-minute exposure period to produce a negative pressure differential inside the test item.

d. Summary of test information required. The following information is required:

(1) Test procedure(s).

(2) Test item configuration.

(3) Rainfall rate.

(4) Test item preheat temperature.

(5) Exposure surfaces/durations.

(6) Wind velocity.

(7) Water pressure.

(8) Water temperature.

(9) Additional guidelines.

4. RAIN TEST FACILITY.

a. The rain facility shall have the capability of producing falling rain up to 10 cm/hr (4 in/hr) accompanied by wind blowing at various angles. The facility temperature shall be uncontrolled, except as regulated by water introduced as rain. The rain shall be produced by a water distribution device of such design that the water is emitted in the form of droplets having a diameter range predominantly between 0.5 and 4.5 millimeters. The rain shall be dispersed completely over the test item when accompanied by the prescribed wind.

b. The wind source shall be positioned with respect to the test item so that it will cause the rain to beat directly, with variations up to 45° from the horizontal, and uniformly against one side of the test item. The wind source shall be capable of producing horizontal wind velocities equal to and exceeding 18 m/s (40 mph). The wind velocity shall be measured at the position of the test item before placement of the test item in the facility. No rust of corrosive contaminants shall be imposed on the test item by the test facility.

c. A water soluble dye such as fluorescein may be added to the rainwater to aid in locating and analyzing water leaks.

5. CONTROLS.

a. The rainfall rate shall be verified immediately before each test.

b. The air velocity shall be verified immediately before each test.

c. Unless otherwise specified, water used for rain tests can be from local water supply sources.

d. Combining tests may produce a more realistic representation of the effects of the environment than a series of single tests can and is therefore encouraged.

6. TEST INTERRUPTION.

a. Undertest interruption. Interruption of a rain test is unlikely to generate any adverse effects, and normally the test shall be continued from the point of interruption.

b. Overtest interruption. Any interruption that results in more extreme exposure of the test item than required by the equipment specification should be followed by a complete operational and physical check. If no problems are encountered, the test item shall be restored to its pretest condition and the test restarted at the point of interruption.

7. PRETEST STANDARD AMBIENT CHECKOUT. All test items require a pretest standard ambient checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Stabilize the test item at standard ambient conditions per the following:

a. Standard ambient. Ambient measurements and checks (e.g., pre-and post-test) are conducted at room ambient conditions as follows:

Temperature:	25°C ± 10°C (77°F ± 18°F)
Relative humidity:	Uncontrolled room ambient
Atmospheric pressure:	Site pressure

b. Controlled ambient. When the ambient conditions must be closely controlled, the following shall be maintained:

Temperature:	23°C ± 2°C (73°F ± 3.6°F)
Relative humidity:	50 percent ± 5 percent
Atmospheric pressure:	$96.45^{+66}_{-10.0}$ kPa
	(725^{+50}_{-70} mmHg)
	($28.5^{+2.0}_{-3.0}$ inHg)

Step 2. Conduct a complete visual examination of the test item.

Step 3. Document the Step 2 results.

Step 4. Prepare the test item in the required test item configuration and install as follows:

a. Installation of test item in test facility. Unless otherwise specified herein or in the equipment specification, measurements and tests shall be made at the following conditions:

(1) Plugs, covers, and inspection plates not used in operation, but used in servicing, shall remain in place.

(2) Electrical connections normally used in service but not in test shall be provided with electrical connectors having dummy cables with protected terminations. Such mechanical connections shall also be protected.

(3) For tests where temperature values are controlled, the test chamber shall be at standard ambient conditions when the test item is installed or as specified in the individual methods.

(4) The test item shall be operated according to the applicable technical order or technical manual, when available, to determine that no malfunction or damage has resulted from faulty installation or handling. The requirement to operate the test item after its installation in the test facility applies only when the item is required to operate during the test.

(5) Test items shall be positioned at least 15 cm (6 inches) from each other or from walls, floors, ceilings, etc., to allow for adequate circulation.

(6) If the item to be tested consists of several separate units, these units may be tested separately provided the functional aspects are maintained as defined in the requirements document.

Step 5. Conduct an operational checkout in accordance with the approved test plan.

Step 6. Record the results for compliance as follows:

a. Post-test data. At the completion of this environmental test, the test item shall be inspected in accordance with the equipment specifications, and the results shall be compared with the pretest data obtained in accordance with:

(1) Pre-test performance record. Before testing, the test item should be operated at standard ambient conditions to obtain and record data determining compliance with the requirements document(s) and for comparison with data obtained before, during, and after this environmental test. The identification and environmental test history of the specific test item(s) should be documented for failure analysis purposes.

b. Pre-test record. The pre-test record shall include (as applicable):

(1) The functional parameters to be monitored during and after the test if not specified in the equipment specification or requirements document. This shall include acceptable functional limits (with permissible degradation) when operation of the test item is required.

(2) Any additional evaluation criteria.

c. Post-test data shall include:

(1) Complete identification of all test equipment and accessories.

(2) The actual test sequence (program) used.

(3) Deviation from the planned test program.

(4) The room ambient test conditions recorded periodically during the test period.

(5) Test item operational data.

(6) A signature and data block for certification of the test data by the test engineer.

(7) Other data as specified in the individual methods or equipment requirements document(s).

NOTE: No sealing, taping, caulking, et cetera shall be used except as required in the test item drawings.

Step 7. If the test item operates satisfactorily, proceed to paragraph 8 RAIN TEST PROCEDURES. If not, resolve the problems and restart at paragraph 7 PRETEST STANDARD AMBIENT CHECKOUT, Step 1.

8. RAIN TEST PROCEDURES. The following test procedures provide the basis for collecting the necessary information concerning the test item's watertightness.

a. Procedure for Blowing Rain.

Step 1. With the test item in the facility and its normal operating position, adjust the rainfall rate to a minimum of 10 cm/hr (4 in/hr). (The sealed test item shall be heated to a higher temperature than the rain water and restored to its normal operating configuration immediately before testing.)

Step 2. Initiate the wind at the velocity of 18 m/s (40 mph) and maintain for at least 30 minutes.

Step 3. If an operational check is required, the test item shall be operated for the last 10 minutes of the 30-minute rain.

Step 4. Rotate the test item to expose to the rain source any other side of the test item that could be exposed to blown rain in its deployment cycle.

Step 5. Repeat Steps 1 through 4 until all possible variations have been accomplished.

Step 6. Examine the test item in the test chamber, if possible; otherwise, remove the test item from the test facility and conduct a visual inspection. If a noticeable amount of free water has penetrated the test item, judgment must be used before operation of the test item. It may be necessary to empty water from the test item to prevent a safety hazard. Measure the volume of water.

Step 7. Measure and document any free water found inside the protected areas of the test item.

Step 8. If required, operate the test item for compliance with the requirements document.

Step 9. Document the results.

9. TEST INFORMATION TO BE RECORDED.

a. Previous test methods to which the test item has been subjected.

b. Results of each performance check and visual examination (and photographs, if applicable).

(1) Pretest.

(2) During test.

(3) Post-test.

(a) Length of time required for each performance check.

(b) Status of the test item for each visual examination.

(c) Exposure durations.

(d) Rainfall rate.

(e) Wind velocity.

(f) Water and test item temperatures.

(g) Water pressure (if applicable).

(h) Surfaces of the test item subjected to rainfall.

10. TOLERANCES FOR TEST CONDITIONS. Unless otherwise specified, tolerances for test conditions shall be as follows:

a. Temperature. The test item shall be totally surrounded by an envelope of air (except at necessary support points). The temperature of the test section measurement system and the temperature gradient throughout this envelope, which is measured close to the test item, shall be within ± 2°C ± (3.6°F) of the test temperature and shall not exceed 1°C per meter or a maximum of 2.2°C total (equipment nonoperating).

b. Pressure. When pressure is 1.3 x 10^{-3} Pa or higher, it shall be measured with an accuracy of ±5 percent of the measured value.

c. Low pressure. When pressure is lower than 1.3 x 10^{-3} Pa, it shall be measured with an accuracy of ±10 percent of the measured value.

d. Humidity. Relative humidity at the chamber control sensor shall be ±5 percent of the measured value.

e. Acceleration. Acceleration shall be measured to within ±10 percent.

f. Time. Elasped time shall be measured with an accuracy of ±1 percent.

11. ACCURACY OF TEST INSTRUMENTATION CALIBRATION. The accuracy of instruments and test equipment used to control or monitor the test parameters shall be verified prior to and following each test and then calibrated in predetermined intervals and get to the satisfaction of the procuring activity. All instruments and test equipment used in conducting the tests specified herein shall:

a. Be calibrated to laboratory standards whose calibration is traceable to the National Standards via primary standards.

b. Have an accuracy of at least one-third the tolerance for the variable be measured. In the event of conflict between this accuracy and a requirement for accuracy in any one of the test methods of this standard, the latter shall govern.

12. CALIBRATION SYSTEM REQUIREMENTS.

a. Calibration System Description: The contractor shall provide and maintain a written description of his calibration system covering measuring and test equipment and measurement standards. This portion dealing with measuring and test equipment shall prescribe calibration intervals and sources and may be maintained on the documents normally used by the contractor to define his inspection operations. The description for calibration of measurement standards shall include a listing of the applicable measurement standards, both reference and transfer, and shall provide nomenclature, identification number, calibration interval and source, and environmental conditions under which the measurement standards will be applied and calibrated. The description system and applicable procedures and reports of calibration shall be available to the Company's or Government's representative.

b. Environmental controls: Measuring and test equipment and measurement standards shall be calibrated and utilized in an environment controlled to the extent necessary to assure continued measurements of required accuracy giving due consideration to temperature, humidity, vibration, cleanliness, and other controllable factors affecting precision measurement. When applicable, compensating corrections shall be applied to calibration results obtained in an environment which departs from standard conditions.

c. Intervals of calibration: Measuring and test equipment and measurement standards shall be calibrated at periodic intervals established on the basis of stability, purpose, and degree of usage. Intervals shall be shortened as required to assure continued accuracy as evidenced by the results of preceeding calibrations provide definite indications that such action will not adversely affect the accuracy of the system. The contractor shall establish a recall system for the mandatory recall of standards and measuring and test equipment within established time limits or interval frequencies.

d. Calibration procedures: Written procedures shall be prepared or provided and utilized for calibration of all measuring and test equipment and measurement standards used to assure the accuracy of measurements involved in establishing product conformance. The procedures may be a compilation of published standard practices or manufacturer's written instructions and need not be rewritten to satisfy the requirements of this standard. As a minimum, the procedures shall specify either the measurement standard to be used for the required accuracy of the standard and the accuracy of the instrument being calibrated. The procedure shall require that calibration be performed by comparison with higher accuracy level standards.

e. Adequacy of the calibration system: The contractor shall establish a procedure to evaluate the adequacy of the calibration system based on out-of-tolerance data generated from calibrating test and measuring equipment. The procedure shall include, but not be limited to, adjustment of calibration frequency, adequacy of the measuring or test equipment, calibration procedures and measuring or test procedures. The procedures shall specifically provide for the identification and prevention or use of any equipment which does not perform satisfactorily.

f. Notification of out-of-tolerance conditions: The contractor's procedure shall include the requirement for the calibration activity to notify the measurement and test equipment user or appropriate contractor element of significant out-of-tolerance conditions so that appropriate action can be taken by the contractor or test and measuring equipment user to correct possible non-conforming products. The procedure shall define what constitutes a significant out of tolerance condition.

g. Domestic contracts: Measuring and test equipment shall be calibrated by the contractor or a commercial facility utilizing standards whose calibration is certified as being traceable to the National Standards, has been derived from accepted values of national physical constants, or has been derived by the ratio type of self-calibration techniques. Standards requiring calibration by a higher level standards laboratory shall be calibrated by a commercial facility capable of providing the required service, a Government Laboratory under arrangements made by the contracting officer, or by the National Bureau of Standards. All standards used in the calibration system shall be supported by certificates, reports, or data sheets attesting to the date, accuracy, and environmental or other conditions under which the results furnished were obtained. All subordinate standards and measuring and test equipment shall be supported by like data when such information is essential to achieving the accuracy control required by this standard. In those cases where no data are required, a suitably annotated calibration label on the item shall be sufficient to satisfy the support data requirements of this paragraph. Certificates or reports from other than the National Bureau of Standards or Government Laboratory shall attest to the fact that the standards used in obtaining the results have been compared at planned intervals with the National Standard either directly or through a controlled system utilizing the methods outlined above. The contractor shall be responsible for assuring that the sources providing calibration services, other than the National Bureau of Standards or a Government Laboratory, are in fact capable of performing the required service to the satisfaction of this standard. All certificates and reports shall be available for inspection by authorized Government representatives.

h. Application and records: The application of the above requirements will be supported by records designed to assure that established schedules and procedures are followed to maintain the accuracy of all measuring and test equipment, and supporting standards. The records shall include an individual record of calibration or other means of control for each item of measuring and test equipment and measurement standards, providing description or identification of the item, calibration interval date of last calibration and calibration results of out-of-tolerance conditions. In addition, the individual record of any item whose accuracy must be reported via a calibration report or certificate will quote the report or certificate number for ready reference. These records shall be available for review by authorized Government personnel.

i. Calibration status: Measuring and test equipment and standards shall be labeled or some other suitable means shall be established for monitoring the equipment to assure adherence to calibration schedules. The system shall indicate date of last calibration, by whom calibrated and when the next calibration is due. The system may be automated or manual. Items which are not calibrated to their full capability or which require functional check only shall be labeled to indicate the applicable condition.

13. STABILIZATION OF TEST TEMPERATURE.

a. Test item operating: Unless otherwise specified, temperature stabilization is attained when the temperature of the operating part of the test item considered to have the longest thermal lag is changing no more than 2.0°C (3.6°F) per hour.

b. Test item nonoperating: Unless otherwise specified, temperature stabilization is attained when the temperature of the operating part of the test item considered to have the longest thermal lag reaches a temperature within test tolerances of the nominal test temperature, except that any critical component (e.g., battery electrolyte for engine starting test) will be within 1°C (1.8°F). Structural or passive members are not normally considered for stabilization purposes. When changing temperatures, for many test items, the temperature of the chamber air may be adjusted beyond the test condition limits to reduce stabilization time, provided the extended temperature does not induce response temperature in a critical component or area of the test item beyond the test temperature limits for the test item.

14. OTHER TESTING FACTORS.

a. Test conditions: Whenever practical, specific test levels, ranges, rates, and durations shall be derived from measurements made on actual or appropriately similar equipment. When specific measured data are not available, the test characteristics shall be tailored using guidance from the contractor's or Government's representative.

b. Performance check during test: When operation of the test item is required during the test exposure, suitable tests shall be performed to determine whether the test exposure is producing changes in performance when compared with pretest data, e.g. data collector, during hot & cold testing, will be exercised.

c. Testing Methods: Each of these test methods contains guidance for handling out-of-tolerance test interruptions. Any such interruption must be carefully analyzed. If the decision is made to continue testing from the point of interruption, to restart the last successfully completed test cycle, or to restart the entire test with the same test item, and a failure occurs, it is essential to consider the possible effects of the interruption or of the extended length of the test.

d. Combined tests: Combinations of tests may produce a more realistic representation of the effects of the environment than a series of single tests can. Combined testing is encouraged.

15. FAILURE CRITERIA. Failure of the test item to meet any one of the following conditions shall constitute a test item failure:

a. Deviation of monitored functional parameters level beyond acceptable limits established in Pre-test Performance Record or other as stipulated by the Contractor's or Government's representatives.

b. Nonfulfillment of safety requirements or the development of safety hazards.

c. Nonfulfillment of specific test item requirements.

d. Changes to the test item which could prevent the equipment from meeting its intended service life or maintenance requirements. (For example: Corroded oil drain plug cannot be removed with specified tools).

e. Deviation from established environmental requirements.

f. Other.

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

APPENDIX III

SHOCK TESTING

1. PURPOSE. Shock tests are performed to assure that materiel can withstand the relatively infrequent nonrepetitive shocks or transient vibrations encountered in handling, transportation, and service environments. Shock tests are also used to measure an item's fragility, so that packaging may be designed to protect it, if necessary and to test the strength of devices that attach equipment to platforms that can crash.

2. ENVIRONMENTAL EFFECTS. Mechanical shocks will excite an equipment item to respond at both forced and natural frequencies. This response, among other things, can cause:

a. Failures due to increased or decreased friction, or interference between parts.

b. Changes in dielectric strength, loss of insulation resistance, variations in magnetic and electrostatic field strength.

c. Permanent deformation due to overstress.

d. More rapid fatiguing of materials (low cycle fatigue).

3. GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS.

This method to be outlined is applicable to all materiel which may be subjected to mechanical shock during its life cycle and specifically applicable to the AISI equipment.

There are often advantages to applying shock and vibration tests before climatic tests, provided that this sequence represents realistic service conditions. Test experience has shown that climate-sensitive defects often show up more clearly after the application of shock and vibration forces.

4. EQUIPMENT TO BE PACKAGED.

Application. This procedure is used for equipment requiring a shipping container. It establishes, also, a minimum critical acceleration level for a handling drop height which may later be furnished to a package designer as an acceptable critical acceleration.

5. TEST CONDITIONS. The test item shall consist of the unpackaged AISI equipment in a nonoperational mode. It shall be subjected to a series of trapezoidal 30-g shock pulses having a time duration to be determined from Table I and the equation:

$$T_D = \frac{2 \quad (2\ h/g)}{A_m}$$

where:

T_D = time duration of Am
h = design drop height
g = 980.6 cm/sec^2 (386 in/sec^2)
Am = peak acceleration magnitude

The pulse will be in accordance with Figure 1. A programmable shock machine will be more than likely be required to produce these test conditions because of the displacement limitations of shakers.

6. RATIONALE. The trapezoidal waveshape was chosen because the computation of velocity change it produces (for comparison with design drop height) is much easier to make and more reproducible than most shock spectrum synthesis routines. Also it provides an upper bound on primary and maximax* shock response spectra for given peak acceleration input levels.

*If measured data area available and utilized: The shock response spectrum required for the test will be determined from reduction of the environmental data to obtain either maximum absolute acceleration spectra or equivalent static acceleration spectra. The spectra will be a composite of spectra for positive and negative directions, sometimes called maximax spectra.

TABLE I

SUGGESTED DROP HEIGHT

Package Gross Weight, Kg (lb)	Type of Handling	Design Drop Height cm (in)	Maximum Test Item Velocity Change,* cm/sec (in/sec)
AISI 0 to 9.1 (0 to 20)**	manual handling	76 (30)***	772 (304)
9.1 to 18.2 (20 to 40)	manual handling	66 (26)	722 (283)
18.2 to 27.2 (40 to 60)	manual handling	61 (24)	691 (272)
27.3 to 36.3 (60 to 80)	manual handling	46 (18)	600 (236)
36.3 to 45.4 (80 to 100)	manual handling	38 (15)	546 (215)
45.4 to 68.1 (100 to 150)	mechanical handling	31 (12)	488 (192)
68.1 to 113.5 (150 to 250)	mechanical handling	26 (10)	447 (176)
113.5 - (250 -)	mechanical handling	20 (8)	399 (157)

* For 100 percent rebound.
** The AISI systems are less than twenty (20) pounds.
*** Minimum height 36".

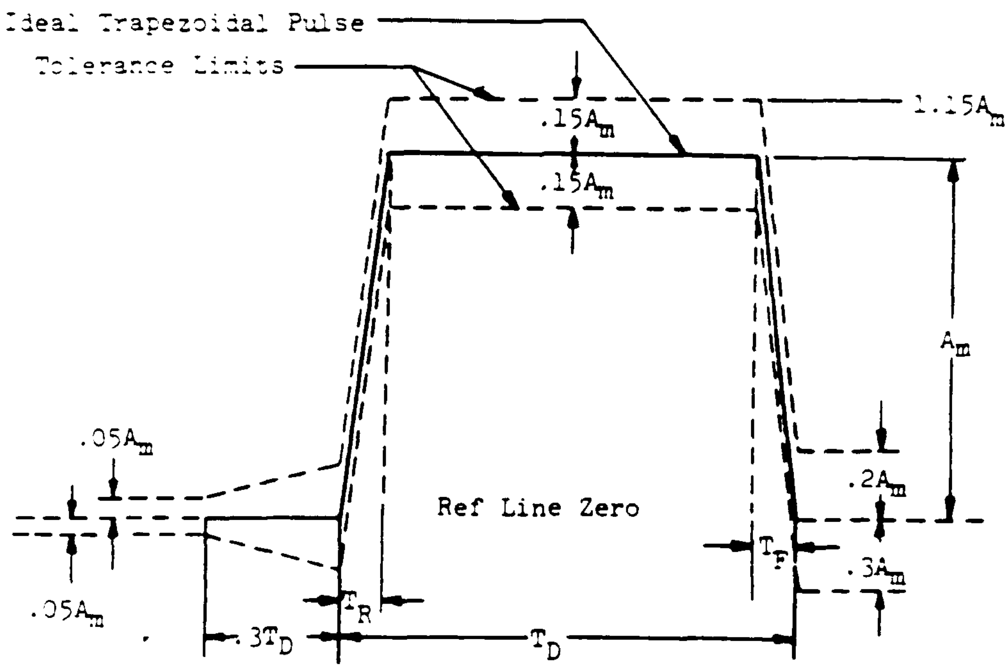


FIGURE 1. Trapezoidal shock pulse configuration.

TOLERANCE LIMITS

TEST	PEAK VALUE (A_m) g's	NOMINAL DURATION (T_D) ms
Fragility	10 to 50	$\frac{2 \quad (2\ h/g)}{A_m}$
Packaged Shock	30	

NOTE: The time history display shall include a time about $3T_D$ long with a pulse located approximately in the center. The peak acceleration magnitude of the trapezoidal pulse is A_m and its duration is T_D. The measured acceleration pulse shall be contained between the broken line boundaries and the measured velocity change (which may be obtained by integration of the acceleration pulse) shall be within ten percent of the ideal pulse. This ideal pulse equals approximately 0.5 A_m g (T_D-T_R-T_F) where rise (T_R) and fall (T_F) times shall be less than or equal to $0.1T_D$. The integration to determine velocity change shall extend from $0.4T_D$ before the pulse to $0.1T_D$ after the pulse.

SHOCK APPARATUS

7. TEST FACILITY. The shock-producing apparatus shall be capable of producing the test conditions as determined by computations utilizing the formula:

$$T_D = 2\,\frac{(2\,h/g)}{A_m} \text{ and Figure 1.}$$

The shock apparatus (probably programmable) may be of the free fall, resilient rebound, nonresilient, hydraulic, compressed gas, electrodynamic shaker, or other activating types capable of producing relatively large displacements.

8. CALIBRATION. The shock apparatus will be calibrated for conformance with this specified test requirement. Two consecutive shock applications to a calibration load shall be produced each of which shall satisfy the Paragraph 5, TEST CONDITIONS. The calibration load shall then be removed and the shock test will be performed on the actual test item.

9. CONTROLS. The instrumentation used to measure shock pulses or shock acceleration spectrá shall have the following characteristics.

a. Accelerometer.

(1) Transverse sensitivity of less than or equal to 5%.

(2) An amplitude linearity within 10% from 5% to 100% of the peak acceleration amplitude required for testing.

b. Analysis system.

(1) Will not allow more than a 5% measurement error into the frequency band of interest. (20 Hz to 10 KHz typically.)

(2) If filters are used to meet the previous requirement, a filter having linear phase-shift characteristics shall be used.

(3) With filter (if used), shall have a pass band within a 1 db across the frequency range specified for the accelerometer. (See a. Accelerometer.)

10. PREPARATION FOR TEST.

a. Preliminary steps. Prior to initiating any testing:

Determine the shock levels necessary for conducting the tests.

b. Pretest checkout. All items require a pretest checkout at standard ambient conditions to provide baseline data. Conduct the checkout as follows:

Step 1. Conduct a complete visual examination of the test item with special attention to stress areas.

Step 2. Document the results.

Step 3. Where applicable, install the test item in its test fixture.

Step 4. Conduct an operational checkout applicable to the necessary testing procedure & plan.

Step 5. Document the results for compliance with the AISI GENERAL REQUIREMENTS portion of this O/E/S TEST PLAN.

Step 6. If the test item operates satisfactorily, proceed to paragraph 11 TEST PROCEDURES. If not, resolve the problem and restart at Step 1.

11. TEST PROCEDURES.

a. Equipment to be packaged.

Step 1. Following the guidance as described in Paragraph 5, TEST CONDITIONS, calibrate the shock machine as follows:

(a) Mount the calibration load (the actual test item, a rejected item, or a rigid dummy mass) to the test apparatus in a manner similar to that of the actual test item. Use a fixture similar in shape and configuration to the shock attenuation system which will support the test item in its shipping container. (The fixture should be as rigid as possible to prevent distortion of the shock pulse imparted to the test item.)

(b) Perform calibration shocks until two consecutive shock applications to the calibration load produce waveforms which are all within the tolerance envelope of the specified waveform as detailed in Figure 1.

Step 2. Remove the calibrating load and install the actual test item on the shock apparatus.

Step 3. Perform a functional test on the test item.

Step 4. Subject the test item to the test pulse.

Step 5. Record necessary test data. This shall include test setup photos, test logs, and photos of the actual test pulse.

Step 6. Perform a functional test on the test item.

Step 7. Repeat steps 2, 3, 4, and 5 once in opposite direction for each of the three orthogonal axes (six shocks).

Step 8. Document results.

12. INFORMATION TO BE RECORDED. Test data shall be recorded as specified in the AISI GENERAL REQUIREMENTS, portion of the O/E/S TEST PLAN and shall include the following:

a. Prior test methods to which the specific test item has been subjected.

b. Pretest data required (see the GENERAL REQUIREMENTS).

c. Shock pulse selection, specifying shape, peak value, and duration.

d. Temperature extremes (if the shock test is done in conjunction with temperature testing).

e. All instrumentation and filtering used.

f. Whether operation during the test is required, mode of such operation, and if and how the operation is to be monitored.

g. Loading and tiedowns.

h. Failure criteria.

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

APPENDIX IV

VIBRATION TEST APPARATUS

1. APPARATUS. Any vibration-inducing machinery capable of satisfying the test conditions, as described and stated in Figures 1-7, is acceptable.

a. Tolerances. The acceleration power spectral density of the test control signal shall not deviate from the specified requirements by more than ±3db over the entire test frequency range. However, deviations of -6db in the test control signal may be granted for frequencies greater than 500 Hz due to fixture resonance, test item resonance, or facility limitations. The cumulative bandwidth over which this reduction shall be allowed cannot be greater than 5% of the test frequency range (see Figure 1). In no case shall the acceleration power spectral density be more than -6db below the specified requirements. No deviation shall be granted for frequencies below 500 Hz. When the test cannot be controlled within ±3db from the specified requirement, at the risk of the tester, the test may continue. The risk shall be to assume no overtesting is occurring, test results are valid, and appropriate corrective action will be taken in accordance with the nature of the test. Tolerance levels in terms of db are defined as:

$$db = 10 \log_{10} \frac{W_1}{W_o}$$

where

W_1 = measured acceleration power spectral density in g^2/Hz units.

W_o = specified level in g^2/Hz units.

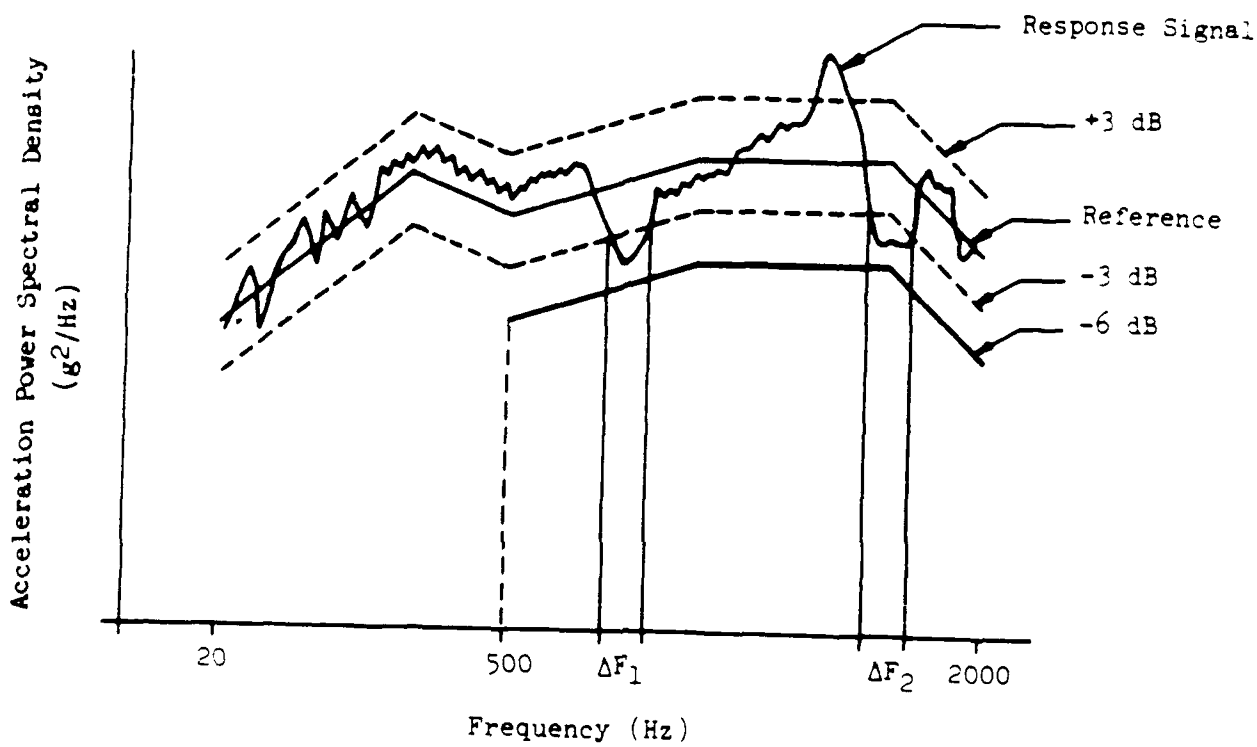
Confirmation of these tolerances shall be made by the use of an analysis system providing at least 100 statistical degrees of freedom. For all procedures using broadband random vibration with random peaks, sinusoidal peaks, or source dwell, analysis systems shall be less than or equal to 10 Hz in bandwidth up to and including the frequency of the highest peak in the test spectrum.

b. Digital analysis. A digital system is the preferred method for performing a power spectral density control and analysis. Digital systems used shall have accuracies in excess of standard analog analysis and control systems. For line contiguous filter, equalization/analysis systems bandwidths should be as follows:

(1) B = 25 Hz, maximum between 20 and 200 Hz

(2) B = 50 Hz, maximum between 200 and 1,000 Hz

(3) B = 100 Hz, maximum between 1,000 and 2,000 Hz



$\Sigma \Delta F_i \leq 5\%$ of Test BW

FIGURE 1. Example of acceptable performance within tolerance.

c. Swept frequency analysis/constant bandwidth. Such systems characterized by constant bandwidth are as follows:

(1) Filter bandwidth as follows:

(a) B = 25 Hz, maximum between 20 and 200 Hz

(b) B = 50 Hz, maximum between 200 and 1,000 Hz

(c) B = 100 Hz, maximum between 1,000 and 2,000 Hz

(2) Analyzing averaging time = T = 2 R'C = 1 second, minimum, where T = True averaging time and R'C = analyzer time constant.

(3) Analysis sweep rate (linear) = $R' = \frac{B}{4RC}$ or

$\frac{B^2}{8}$ (Hz/second) maximum, whichever is smaller.

d. Sweep frequency analysis/constant percentage bandwidth analyzer.

(1) Filter bandwidth = pf_c = one-tenth of center frequency maximum ($0.1f_c$), where p = percentage and f_c = analyzer center frequency.

(2) Analyzer averaging time = $T = \frac{50}{pf_c}$ minimum

(3) Analysis sweep rate (logarithmic) = $R' = \frac{pf_c}{4RC}$

or $\frac{(pf_c)^2}{8}$ (Hz/second) maximum, whichever is smaller.

2. PREPARATION FOR TEST.

a. General preparation.

Step 1. Prepare the test item in accordance with the O/E/S GENERAL REQUIREMENTS, and as specified for in this VIBRATION TEST PLAN.

Step 2. Examine the test item for physical defects, etc., and document the results.

Step 3. Conduct an operational check and document the results.

Step 4. The test setup shall be as follows: Each individual AISI test item system shall be attached to the vibration generator directly or with a fixture, and securely held by its normal means of attachment. The fixture shall incorporate actual service structures as much as possible to minimize unrealistic response characteristics during test exposure. Any connection to the test item, such as cables pipes, wires, and the like, shall be arranged so that it imposes restraints and mass similar to those present when the equipment is installed in the operational configuration. Excitation shall be applied through the three orthogonal axes of the test item.

Step 5. Proceed to paragraph 3 TEST PROCEDURES if no problems are found; otherwise, correct the problems and restart test with Step 2.

3. TEST PROCEDURES.

Step 1. Inspect test item to establish pre-test criteria and physical condition.

Step 2. Verify the test items' functionality.

Step 3. Mount the test item on vibration equipment providing the vibrational inputs available to secured cargo.

Step 4. Expose the test item to the test level and duration as determined from Figures 2 through 7.

Step 5. Inspect the test item and compare it to pre-test data and physical condition. If applicable, verify the test item functionality and record the results.

Step 6. Repeat Steps 1 through 5 for each of the three (3) orthogonal axes.

Step 7. Document the test results in accordance with paragraph 4, INFORMATION TO BE RECORDED.

4. INFORMATION TO BE RECORDED.

a. Prior test history of the specified test item.

b. Inspection and test procedures, including inspection requirements, test criteria, instrumentation, data requirements, and failure criteria.

c. List of all test equipment, including vibration generating and analysis equipment, mounting arrangements, and fixtures.

d. Orientation of test item, including axes of applied vibration.

e Location & type of accelerometers used to control and measure vibration.

f. Resonant frequencies, including those selected for test, as applicable.

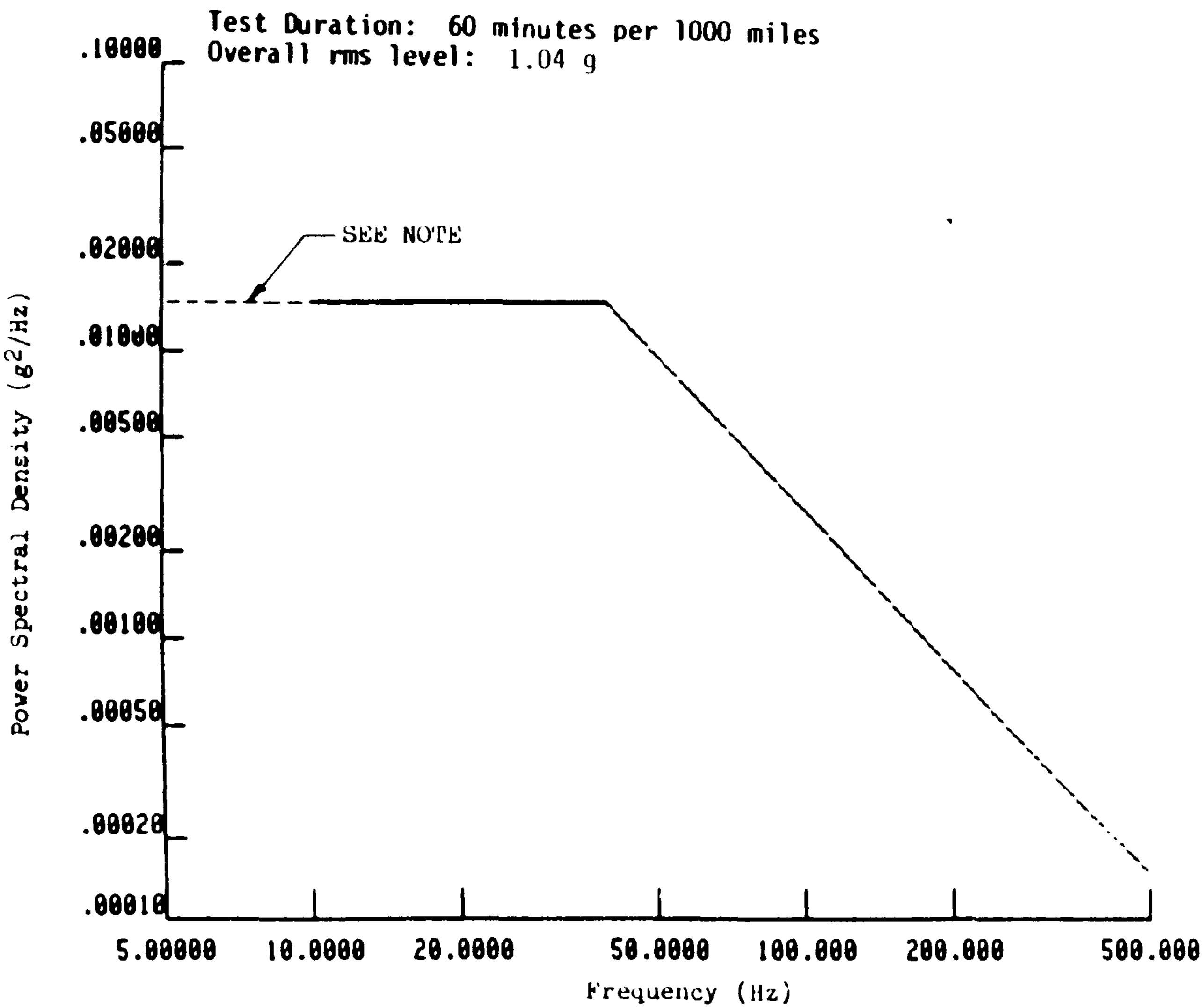
g. Isolation characteristics, including sway amplitudes and transmissibility versus frequency.

h. Applied test levels, durations, and frequency ranges.

i. Results of all performance measurements, including overall test results.

j. Analysis of each failure and corrective action proposed.

k. Analysis bandwidth.



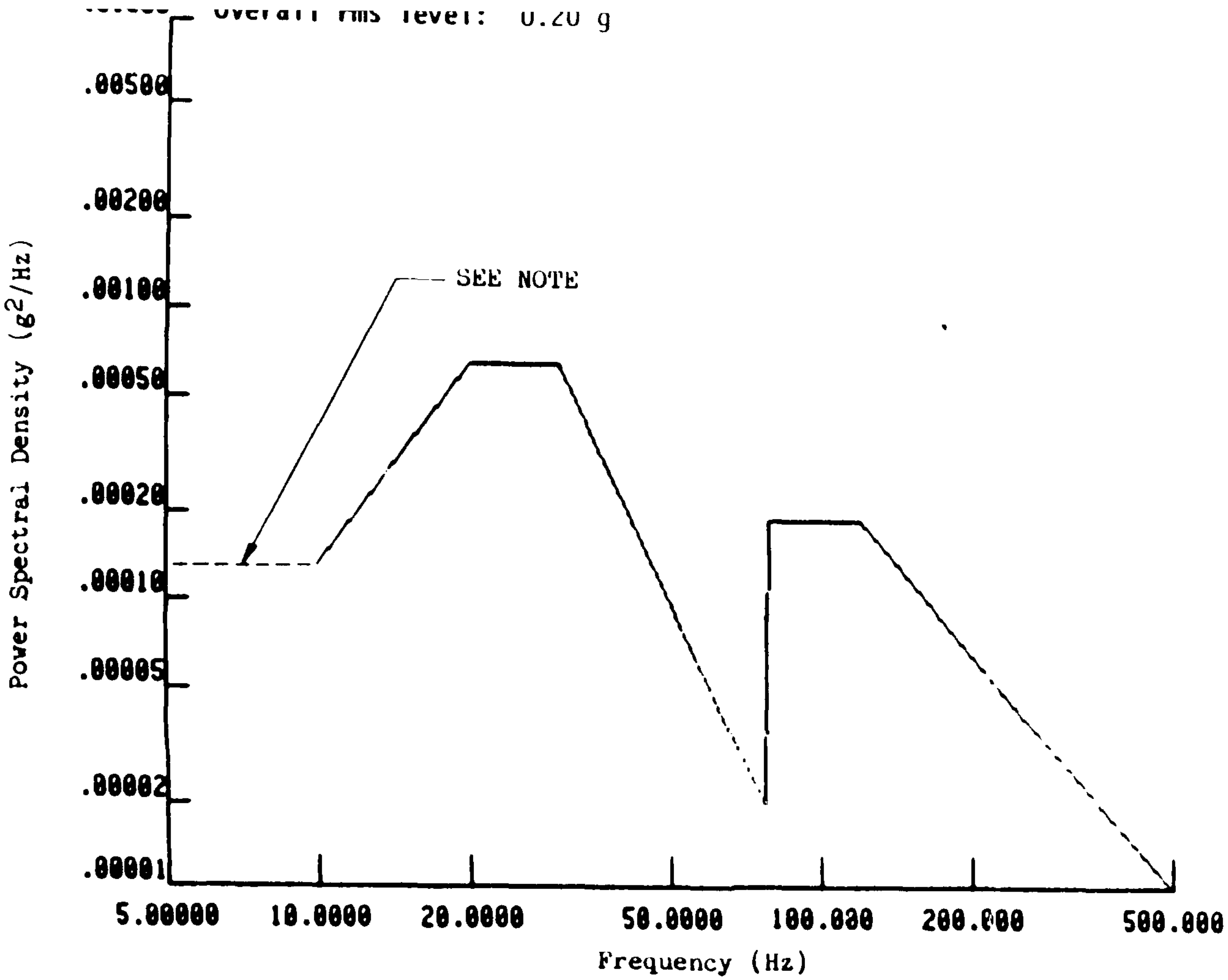
BREAKPOINTS	
FREQ	PSD VALUE
10	.01500
40	.01500
500	.00015

NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

FIGURE 2 <u>Basic transportation, common carrier environment, vertical axis</u>.

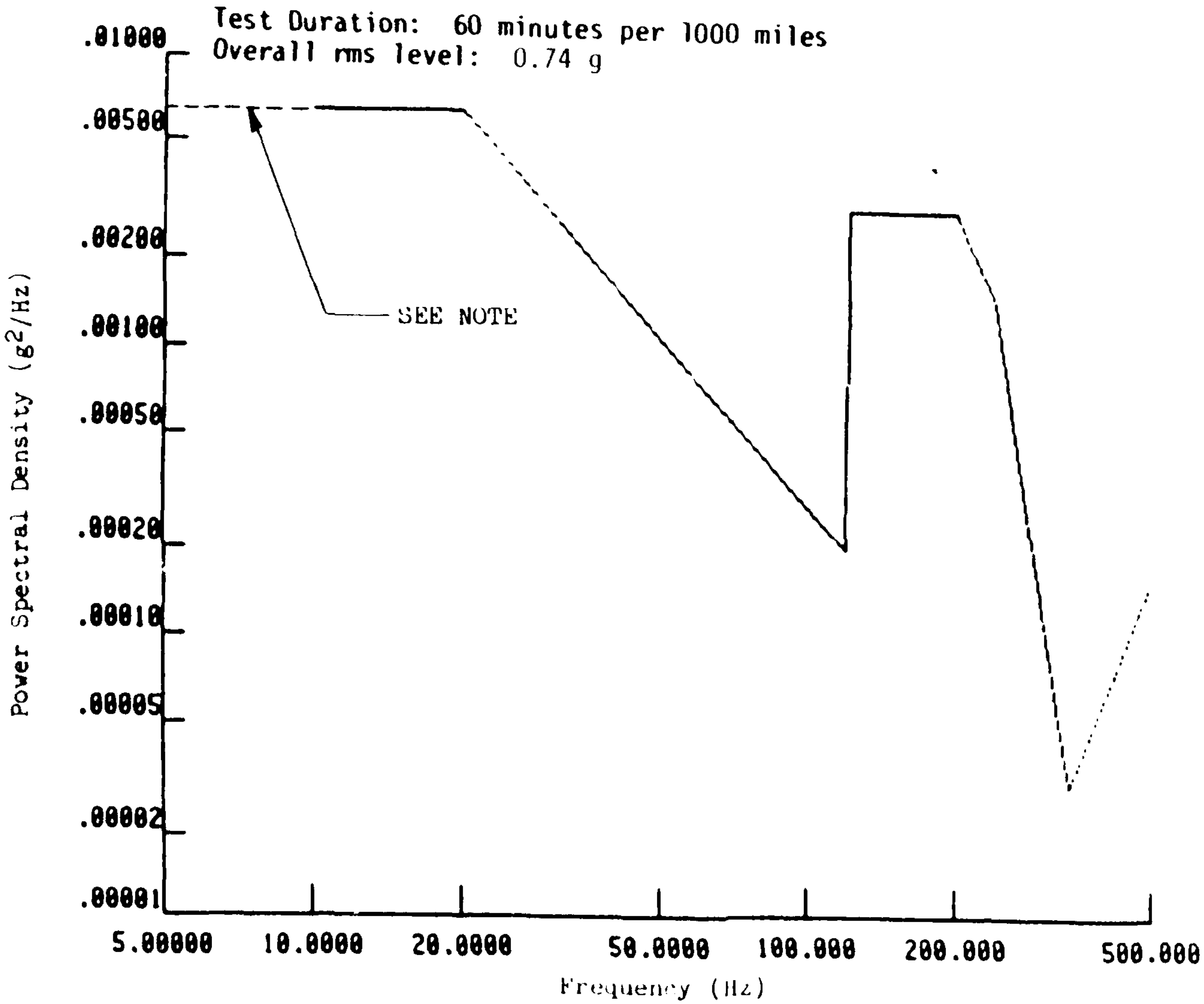
Overall rms level: 0.20 g

FREQ	PSD VALUE
10	.00013
20	.00065
30	.00065
78	.00002
79	.00019
120	.00019
500	.00001



NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

FIGURE 3 <u>Basic transportation, common carrier environment, transverse axis</u>.



BREAKPOINTS

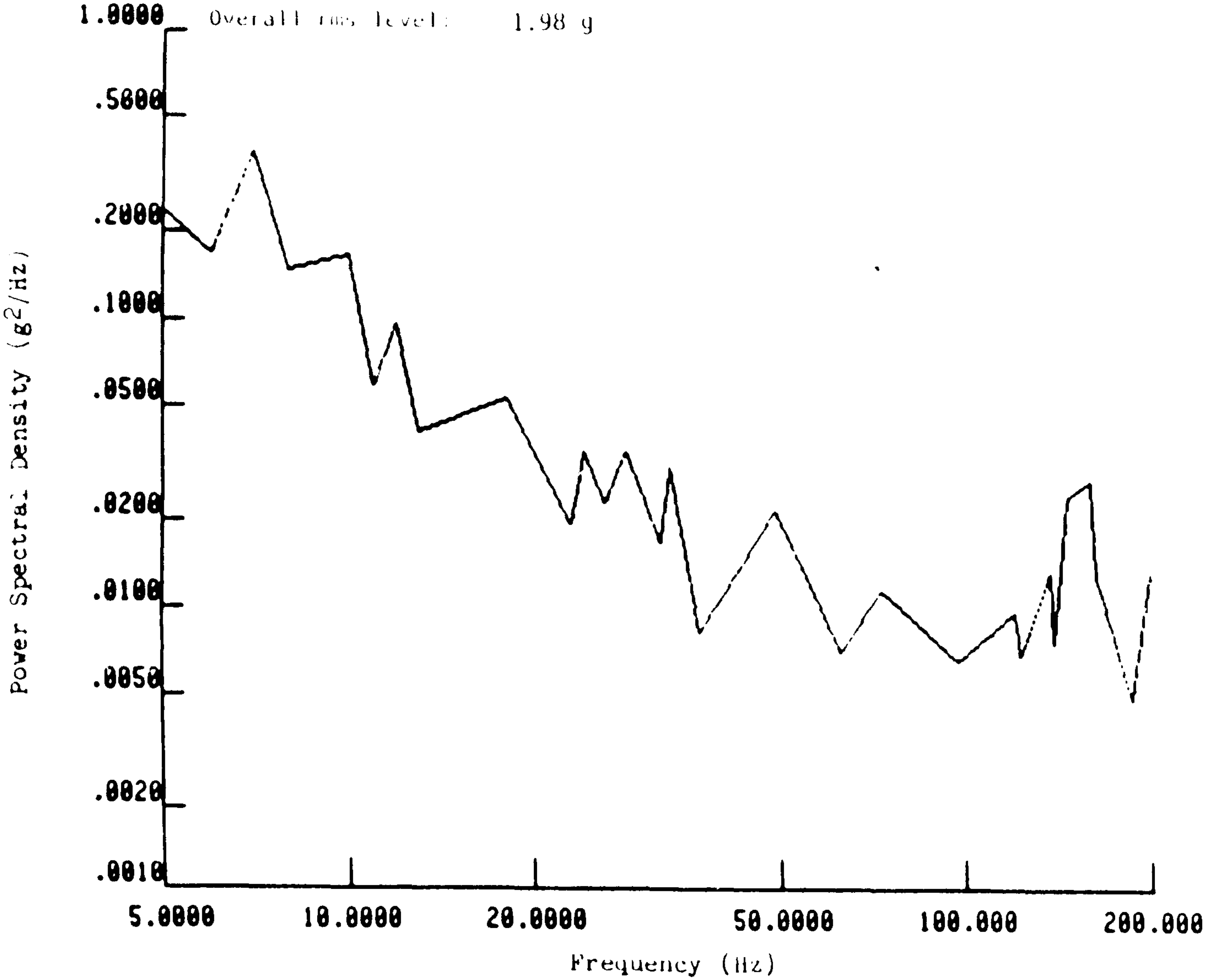
FREQ	PSD VALUE
10	.00650
20	.00650
120	.00020
121	.00300
200	.00300
240	.00150
340	.00003
500	.00015

NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

FIGURE 4 Basic transportation, common carrier environment, longitudinal axis.

Test Duration: 60 minutes per 250 miles

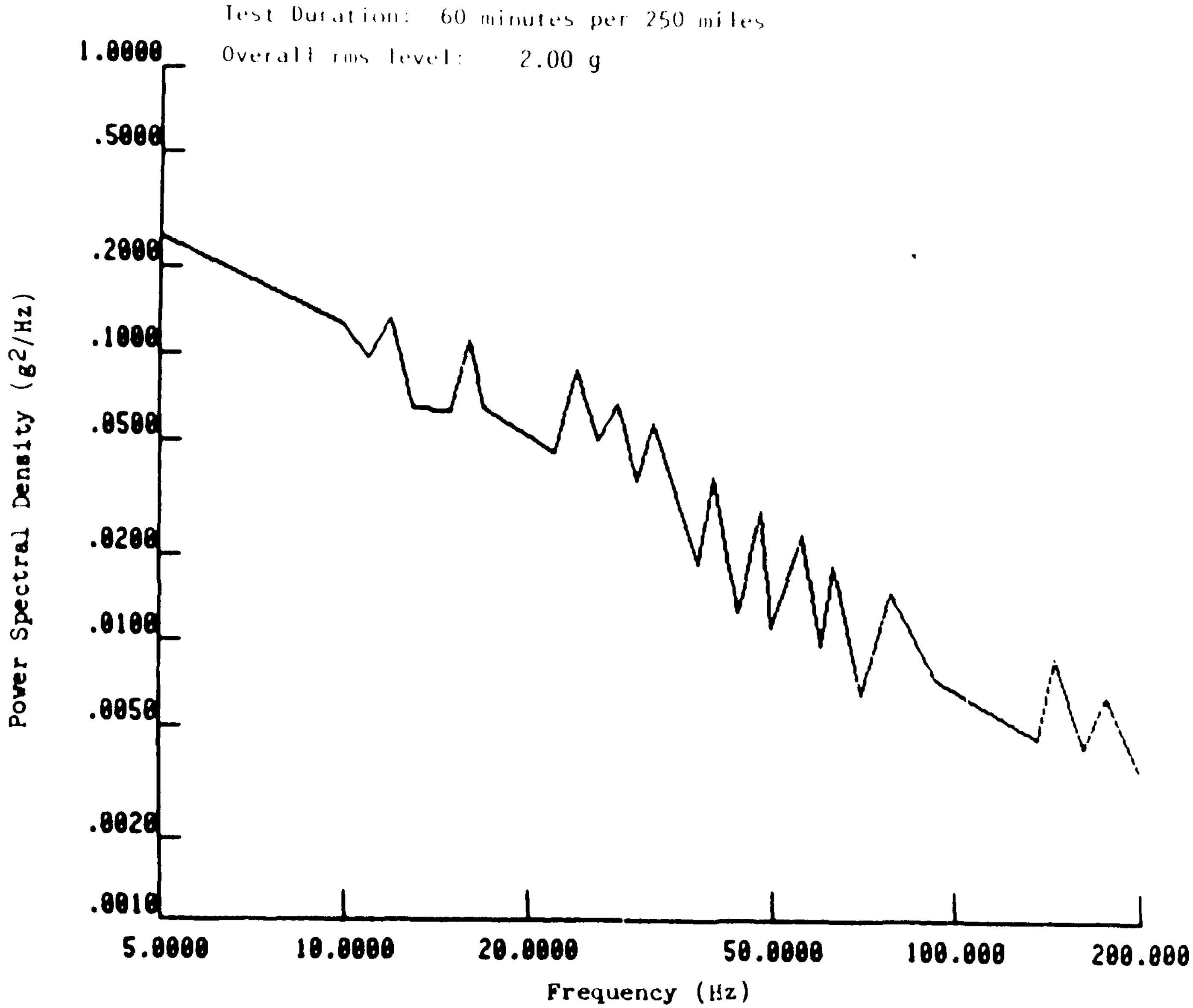
Overall rms level: 1.98 g



BREAKPOINTS

FREQ	PSD VALUE
5	.23840
6	.16840
7	.38230
8	.14870
10	.16840
11	.05930
12	.09750
13	.04090
18	.05370
23	.01940
24	.03520
26	.02310
28	.03520
32	.01670
33	.03110
37	.00810
49	.02190
63	.00700
73	.01150
98	.00660
120	.00970
123	.00680
138	.01340
140	.00760
146	.02490
159	.02820
163	.01300
188	.00480
200	.01340

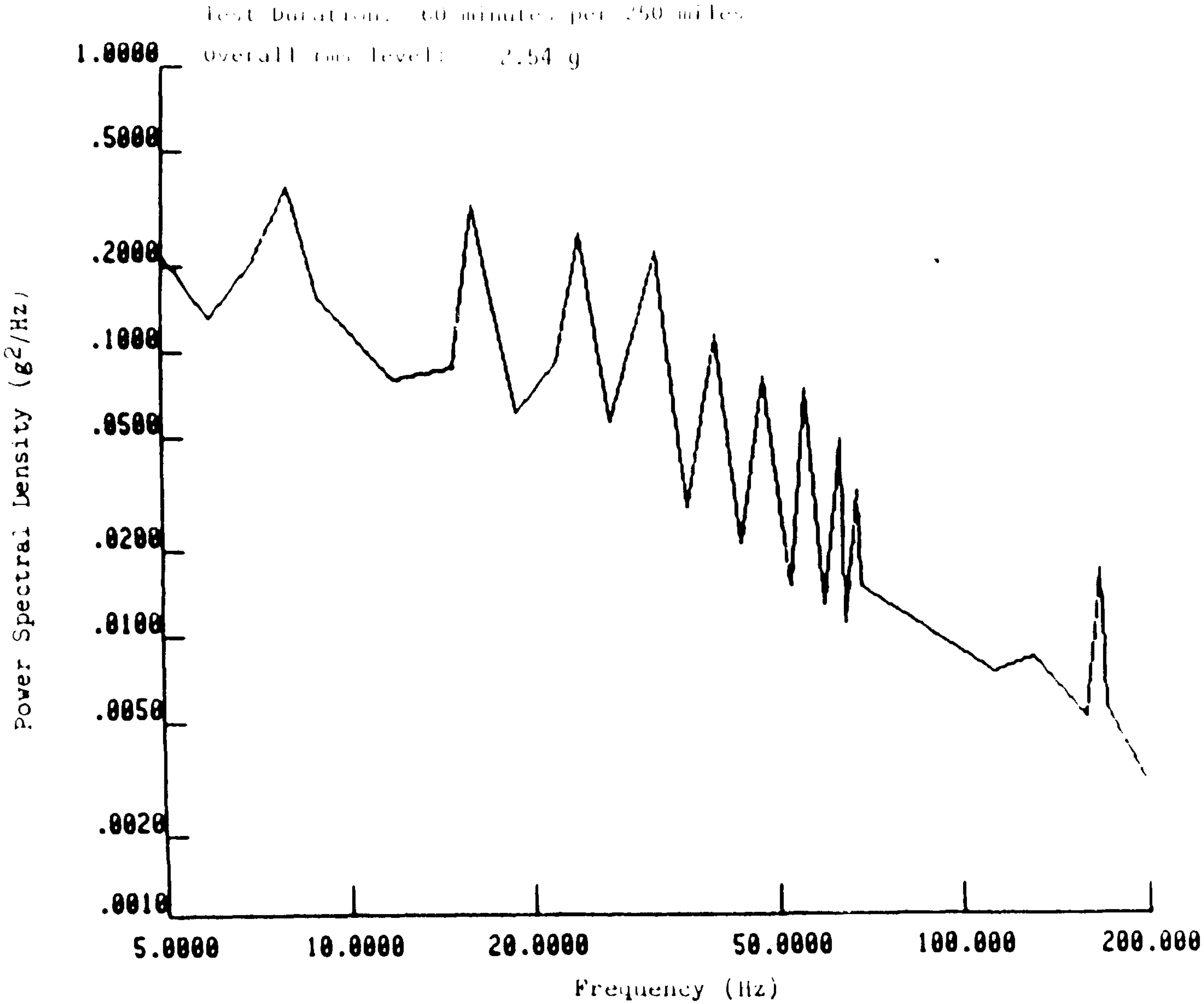
FIGURE 5 Basic transportation, composite tactical wheeled environment, vertical axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.25490
10	.13030
11	.09670
12	.13360
13	.06500
15	.06340
16	.11230
17	.06500
22	.04590
24	.08980
26	.05070
28	.06830
30	.03670
32	.05880
38	.01920
40	.03860
44	.01290
48	.02940
50	.01140
56	.02460
60	.00960
63	.01880
70	.00660
78	.01500
93	.00730
137	.00460
145	.00910
162	.00430
176	.00660
200	.00360

FIGURE 6 Basic transportation, composite tactical wheeled environment, transverse axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.22130
6	.13140
7	.20540
8	.38230
9	.15630
12	.07990
15	.08830
16	.32940
19	.06080
22	.09280
24	.26340
27	.05540
32	.22690
36	.02820
40	.11600
44	.02090
48	.08190
53	.01480
56	.07420
60	.01270
64	.04980
65	.01100
68	.03260
69	.01480
114	.00740
132	.00830
160	.00510
169	.01710
173	.00550
200	.00310

FIGURE 7 Basic transportation, composite tactical wheeled environment, longitudinal axis.

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

APPENDIX V

OPERATIONAL FIELD TEST

A. TRIANGULATION: Reciprocal vertical angles should be observed at times of best atmospheric conditions (between noon and late afternoon) for all orders of accuracy. Electronic distance measurements need a record at both ends of the line of dry bulb temperatures to ±1°C, and barometric pressure to ±5 mm of mercury. The theodolite and targets should be centered to within 1 mm over the survey mark or eccentric point.

SECOND ORDER CLASS II

Directions	
Number of poisitions	8 or 12+
Standard deviation of mean not to exceed	0.8"
Rejection limit from the mean	5"
Reciprocal Vertical Angles (along distance sight path)	
Number of independent observations direct/reverse	2
Maximum spread	10"
Maximum time interval between reciprocal angles (hr)	1
Astronomic Azimuths	
Observations per night	16
Number of nights	1
Standard deviation of mean not to exceed	0.6"
Rejection limit from the mean	5"
Electro-Optical Distance	
Minimum number of days	1
Minimum number of measurements/day	2§
Minimum number of concentric observations/measurement	1
Minimum number of offset observations/measurement	2
Maximum difference from mean of observations (mm)	50
Minimum number of readings/observation (or equivalent)	10
Maximum difference form mean of reading (mm)	++
Infrared Distances	
Minimum number of days	1
Minimum number of measurements	2§
Minimum number of concentric observations/measurements	1
Minimum number of offset observations/measurements	1
Maximum difference from mean of observations (mm)	5
Minimum number of readings/observation (or equivalent)	10
Maximum difference from mean of reading (mm)	++

+ 8 if 0.2", 12 if 1.0" resolution
§ one measurement at each end of line.
* two or more instruments.
++ as specified by manufacturer.

B. TRAVERSE: Electronic distance measurements need a record at both ends of the line of dry bulb temperatures to ±1°C and barometric pressure to ±5 mm of mercury. The theodolite, EDM, and targets should be centered to within 1 mm over the survey mark or eccentric point.

SECOND ORDER CLASS II

Directions	
Number of positions	6 or 8*
Standard deviation of mean not to exceed	0.8"
Rejection limit from the mean	5"
Reciprocal Vertical Angles	
(along distance sight path)	
Number of independent observations direct/reverse	2
Maximum spread	10"
Maximum time interval between reciprocal angles (hr)	1
Astronomic Azimuths	
Observations per night	12
Number of nights	1
Standard deviation of mean not to exceed	0.6"
Rejection limit from the mean	5"
Electro-Optical Distance	
Minimum number of measurement	1
Minimum number of concentric observations/measurement	1
Minimum number of readings/observation (or equivalent)	10
Maximum difference from mean of readings (mm)	§
Infrared Distance	
Minimum number of measurements	1
Minimum number of concentric observations/measurement	1
Minimum number of offset observations/measurement	1++
Maximum difference from mean of observations (mm)	10++
Minimum number of readings/observation	10
Maximum difference from mean of readings (mm)	§

+ 8 if 0.2", 12 if 1.0" resolution.
* 6 if 0.2", 8 if 1.0" resolution
§ as specified by manufacturer.
++ only if decimal reading near 0 or high 9's.

C. GEODETIC LEVELING: Compensator-type instruments should be checked for proper operation at least every 2 weeks of use. Rod calibration should be repeated whenever the rod is dropped or damaged in any way. Rod levels should be checked for proper alignment once a week. The manufacturer's calibration standard should, as a minimum, describe scale behavior with respect to temperature.

SECOND ORDER CLASS II

Minimal observation method.. 3-wire

Section running.. SRDS OR DR*

Difference of forward and backward sight lengths never to exceed
per setup (m).. 10
per section (m).. 10
Maximum sight length (m).. 70
Minimum ground clearance of line of sight (m).......................... 0.5
Even number of setups when not using leveling rods with detailed calibration.. yes
Maximum section misclosure (mm).. 8/D
Maximum loop misclosure(mm).. 8/E
3-wire method Reading check (difference between top and bottom intervals) for one setup not to exceed (nths of rod units).................... 2
Read rod 1 first in alternate setup method......................... yes

Double scale rods
Low-high scale elevation difference for one setup not to exceed
(mm) with reversible compensator.................................. 2.00

Other instrument types:
Half-centimeter rods.. 0.70
Full-centimeter rods.. 0.70

(SRDS-Single-Run, Double Simultaneous procedure)
(DR-Double-Run)
D-shortest length of section (one-way) in km
E-perimeter of loop in km
* May single-run if line length between network control points is less than 25 km.

Double-run leveling may always be used, but single-run leveling done with the double simultaneous procedure may be used only where it can be evaluated by loop closures. Rods should be leap-frogged between setups (alternate setup method). The date, beginning and ending times, cloud coverage, air temperature (to the nearest degree), temperature scale, and average wind speed should be recorded for each section plus any changes in the date, instrumentation, observer or time zone. The instrument need not be off-leveled/releveled between observing the high and low scales when using an instrument with a reversible compensator. The low-high scale difference tolerance for a reversible compensator is used only for the control of blunders.

With double scale rods, the following observing sequence should be used:

backsight, low-scale
backsight, stadia
foresight, low-scale
foresight, stadia
off-level/relevel or reverse compensator
foresight, high-scale
backsight, high-scale

AUTOMATED INTEGRATED SURVEYING INSTRUMENT

APPENDIX VI

RADIATION PROTECTION CALCULATION

Wavelength Range: 800 to 1060 nm

Exposure Time Range: 100s to 3×10^4 s

Defining Aperture: 7mm

Protection Standard = $100 C_A \mu w \cdot cm^{-2}$

Where $C_A = e^{[(\lambda - 700) \div 224]}$

and $\lambda = 865$ nm

$C_A = 2.08$

Therefore

Protection Standard = $100 \times 2.08 \mu w \cdot cm^{-2}$

= $208 \mu w \cdot cm^{-2}$

Maximum Power = Protection Standard x Defining Aperture

= $208 \mu w\text{-}cm^{-2} \times \frac{\pi(.7)^2}{4}$

= $80.1 \mu w$

Limit Set by Military Standard is:

Max Power Limit = 5 x Max. Power

= $5 \times 80.1 \mu w$

= $400.5 \mu w$

Auto Ranger II-X

Wave Length: 865nm

Transmitter Area $23.4 cm^2$

Using 400 μw as maximum output power, then the irradiance is:

Irradiance = $\frac{400 \mu w}{23.4 cm^2}$

= $17.1 \mu w \cdot cm^{-2}$

Margin of safety on irradiance is:

$$\text{Margin} = \frac{208\,\mu w/cm^2}{17.1\,\mu w/cm^2} = 12.1$$

Since the margin for irradiance is greater than a factor of ten, the controlling factor is total output power.

APPENDIX VII

FIELD OPERATIONAL CHECK SHEETS

CHECK SHEETS PAGE

AISI TEST TASK SHEET

Task No. 1 Task Name Known Base Line Measurement

Functional Procedure	Data Used For	Output Printr.	Output Plotter
1. Measure distance (EDM)	Reduce measured distance	X	
2.	Compute distance between points	X	X
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 2

Task Name Differential Leveling

Functional Procedure	Data Used For	Output Printer	Output Plotter
1. Take level readings	Computing differential level data	*	
2. Take horz. < readings	Computing distance between points	*	*
3. Take distance reading (EDM)	Reduce measured distances	*	
4. Take distance readings (stadia)	Compute stadia information	*	*
5. Take vert. < readings	Draw topographic maps of survey sites		*
6.	Draw three-dimensional perspective of survey sites		*
7.	Compute level values (Wisconsin method)	*	
8.	Reduce stadia-transit information		*
9.	Compute differential level data (least square)	*	*
10.	Check differential level observations	*	

AISI TEST TASK SHEET

Task No. 3   Task Name Plane Traverse

Functional Procedure	Data Used For	Output Prntr.	Output Plotter
1. Measure	Layout 3rd order traverse stations		X
2. Measure distance	Compute differential level data	X	
3. Measure elev.	Compute distance between point	X	X
4. Measure azimuth	Compute plane traverse data	X	X
5. Establish starting coord.	Reduce measured distance	X	
6.	Compute allowable error and adjust station	X	X
7.			
8.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 4

Task Name Preliminary Location Survey (Road or Airfield) (Planetable Survey)

Functional Procedure	Data Used For	Output Printer	Output Plotter
1. Measure	Plot profile and cross-section for cut and fill		X
2. Measure	Compute amount of earthwork for cut and fill		X
3. Measure distance	Compute differential level data	X	
4. Measure azimuth	Compute distance between points	X	X
5. Locate pt. from known pt.	Draw topographic map of survey site		X
6. Measure stadia distance	Draw three-dimensional perspective of survey sites		X
7. Perform radial shots	Draw profiles and cross-section		X
8. Establish control pts.	Compute end areas from cross-sections	X	
9.	Reduce measured distances	X	
10.	Compute stadial information	X	X

AISI TEST TASK SHEET

Task No. 5

Task Name Final Layout (Roads and Airfields) (data from initial location)

Functional Procedure	Data Used For	Output Prntr.	Output Plotter
1. Compute	Uploading to data collector for performing final layouts	X	X
2. Compute grade stake info.	in field. Hard copy data will be used to perform final	X	X
3. Compute vertical curve	layout in field by manual input to get time comparison.		
4. Compute /grade/shoulder and slope stake info.	The final , grade, shoulder/slope stakes will be	X	X
5. Compute H. curve using arc, chord and military det.	located in the field using conventional survey methods.	X	X
6. Compute bridge abatment layout	Bridge abatement will be staked.		
7. Perform radial shots			
8. Establish control pts.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 6

Task Name Building and Utility Set Preliminary Survey

Functional Procedure	Data Used For	Output: Printr.	Output: Plotter
1. Measure	Compute differential level data	X	
2. Measure	Compute distance between points	X	X
3. Measure distance	Draw topographic map at survey site	X	X
4. Establish control pt.	Draw profile and cross-sections		X
5. Measure azimuth	Reduce measured distance	X	
6. Carry known point	Compute allowable error and adjust traverse	X	X
7. Location forward	Locate section/township/subdivision corners	X	X
8.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 7

Task Name Building and Utility Layout

Functional Procedure	Data Used For	Output Prntr.	Output Plotter
1. Compute building layout	Taking to field and performing the layout using	X	X
2. Compute batter board	conventional surveying methods.	X	X
3. Location and level			
4. Compute utility		X	X
5. Line staking (offset)			
6.			
7.			
8.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 8 **Task Name** Solar Observation

Functional Procedure	Data Used For	Output Prntr.	Output Plotter
1. Direct/Reverse angles measured	Computation of azimuth	X	
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 9 Task Name Astronomic Observation (Star Shot)

Functional Procedure	Data Used For	Output Prntr.	Output Plotter
1. Direct/Reverse angles measured	Compute azimuth	X	
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 10

Task Name Known Base Line Measurement

Functional Procedure	Data Used For	Output Prntr.	Output Plotter
1. Measure distance	Instrument accuracy validation		
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

AISI TEST TASK SHEET

Task No. 11 Task Name Maximum Range (EDM) Verification

Functional Procedure	Data Used For	Output Prntr.	Output Plotter
1. Measure distance			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

COGO Checklist

File Handling

The ability to create and manipulate files for coordinate storage. Optionally, files may contain unreduced raw field data, descriptive information, plot sequences and a record of keystrokes. The more file handling routines contained within the program, the better. Typically, some basic file handling routines are handled within the program, while the more advanced functions must be performed by exiting to the operating system.

Tasks/functions to look for include.

- Create a File - User may name a file (project, job, etc.) and create storage space where all coordinates for that project will be stored. There may be restrictions on the minimum and maximum number of points per file.
- Change a File - Renames or changes descriptive header information (e.g., client name, job name, et.) about a file.
- Extend a File - Expands the number of points in a file. Useful when the number of points, goes beyond the original number set up. Sometimes this is done automatically.
- Merge Two Files - Combines two different jobs into one file.
- Purge a File - Erases a file.
- Copy a File - Backs up, or copies, individual data files.
- Catalog of Files - Lists the names of all files on a disc. Optionally, may include more descriptive information about each file.
- Copy Entire Disc - Backs up, or copies, all data files on a disc.
- Coordinate Transfer (Any block of points) - Transfers a user specified range of coordinates from one file to another. Useful for working in separate jobs, with common boundaries.
- Format Disc - The process by which the user erases all exisiting data and formats a disk to accept data in accordance with operating system or program requirements. Usually done with a new disc, prior to initial use.

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Overall Data Entry & Computation

Refers to the entry and computation of values, such as coordinates, distances, directions, areas, etc. Accuracy, precision and flexibility of data entry are important considerations.

Tasks/Functions to look for include:

- Computed Precision - The precision to which coordinates, distances, directions, and areas are computed by the program. Usually depends upon the significant digits possible within the computer or the software program.

- Stored Precision - The precision to which coordinates, distances, and directions are stored by the program.

- Maximum Significant Digits - The maximum number of digits possible for coordinates, distances, directions, and areas. For example, there is no sense using the actual state plane coordinates for your computations, if your computations are handled by a floating point system, with an 8 place mantissa, since a coordinate value of 1,234,567.892 might be used as 1,234,567.9.

- Digits To the Right of Decimal - User may specify number of digits output to the right of the decimal for coordinates, distances, directions, and areas. Values should be computed to the highest possible precision, but may be printed as specified by the user.

- Directions & Distance Conventions/Units - The ability of the program to accept, compute, output and store different conventions/units for directions and distances. Directions may be bearings, north azimuth, south azimuth, deflection left/right, angle left/right, etc. Distances may be in feet, meters, chains, etc. Some programs accept unreduced field notes that contain rod readings, stadia readings, etc. These are then automatically reduced to coordinate by the program.

- Point Protection - Protects existing points from being overwritten by the program. Operator is usually given the option to overwrite the point or choose a new point number.

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Field Traverse

The entry, reduction and adjustment of observed field data, such as slope distance, vertical angle, horizontal angle, target height, instrument height, EDM offset, rod readings, etc. The entry and use of constants (curvature of the earth, refraction of light, temperature, chain tension, scale, etc.) for use in reduction computations should be an integral part of these routines. Some of these reductions may be made by the field intsrument or data collector, but it is a good idea to have them, in case they are needed. Standard adjustments should also be included.

Tasks/functions to look for include:

- Sideshots - Are sideshots entered during raw traverse data entry or after adjustments? Some programs give you the option of both. If input with raw traverse data, they may be recomputed, based upon adjusted coordinates, or left unadjusted, so be careful.

- Manual or Auto. Pt. Numbering - The ability of the program to automatically number points in sequence. Some programs number sequentially, but not automatically (a "+" is entered instead of the next point number). May provide the capability to switch back and forth between auto and manual numbering.

- Types of Traverse - Refers to the types of traverse the program will handle. Maximum number of courses, type of directions allowed (angle right/left, deflection right/left, bearings/azimuths) and whether elevations may be carried with the traverse are important considerations. The ability to enter point descriptors is also important. Some programs provide the ability to use the last entered angle code as a default. If your traverses are all angle right, this saves one step per leg. In addition, it is sometimes possible to temporarily store a long traverse and restart raw data entry at a later time. Types of traverses to look for include:

  - Closed (Internal Reference) - The beginning and ending points are the same and the reference direction is one of the traverse legs.

  - Closed (External Reference) - The beginning and ending points are the same and the reference direction is external to the traverse.

  - Point to Point - The beginning and ending points are different, but have fixed coordinates.

  - Open - The beginning and ending points are different and only the beginning point has fixed coordinates. No adjustments are possible.

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- Saves Raw Data Separately - Program saves unadjusted raw data (directions and distances) in a separate raw data file. Some programs require the creation and transfer of data to a separate file, while others automatically create a separate "field file" as a subset of the main coordinate file. Very important, especially if you want to run mutliple closures on the same data, or you need to come back at a later time to correct some undetected error.

- Multiple Adjustments - The ability of the program to perform different types of common adjustments. May be possible to perform all adjustments and compare coordinates. Closing distance, difference in closing and starting coordinates, angular misclosure, ratio of precision, distance traversed and area may be computed and printed. Errors and precision should be computed before angle balancing and adjustment. Some programs are able to automatically find this error of closure by holding each leg in turn and printing a report of the trial closures. Adjustment types may include:

  - Least Squares - Simultaneously adjusts the angular and linear measurements to make the sum of the squares of the residuals a minimum.

  - Compass Rule - The correction to be applied to the latitude of any course is to the total error in latitude as the length of the course is to the length of the traverse. The corrections to the departures follow the same rule.

  - Crandall Rule - The angular misclosure is first distributed in equal portions to all the measured angles. The adjusted angles are then held fixed and all remaining corrections placed in the linear measurements through a weighted least squares procedure.

  - Transit Rule - The correction to be applied to the latitude of any course is to the total error in latitude as the latitude of that course is to the arithmetical sum of all the latitudes in the traverse. The corrections to the departures follow the same rule.

  - No Adjustment - No adjustment is performed. Raw data is used to calculate coordinates.

  - Angle Balance - Spreads the total angular error among the turned angles. Usually spreads the error equally, but may include the option to spread the error as the user sees fit or hold specific angles. Sometimes done before adjustment.

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• Insert Leg - Inserts a missing leg in a traverse. Balancing and adjustment is then performed on the corrected data.

• Delete Leg - Deletes an extraneous or incorrect leg from a traverse. Balancing and adjustment is then performed on the corrected data.

• Correct Leg - Corrects a direction and/or distance of any traverse leg. May be performed before, or after, closure is determined. Balancing and adjustment is then performed on the corrected data.

• Hold Leg - Holds a known true leg. Balancing and adjustments are not performed on the held leg.

Coordinate Geometry

The use of coordinate geometry equations to calculate coordinates of points, areas, intersections of lines and curves. The computation of line and curve parameters such as bearing, distance, central angle, etc. are also included.

Two outstanding features, multiple point computation and lines, are not part of any one task/function and deserve special mention.

Mulitple point computation refers to the ability of the program to automatically perform similar computations on groups, or ranges, of points, rather than on a point to point basis. This saves keystrokes and increases productivity. Routines that take advantage of this benefit include; auto traverse and inverse, divide a line, street intersection, cul-de-sacs, point/traverse intersection, etc.

A lines routine, on the other hand, may combine such functions as traverse, inverse, bearing/bearing, etc. into one routine. The user merely enters the known information and the computer automatically performs the correct computation.

Tasks/functions to look for include.

• Area Computations - Computes areas using known points.

• Cogo Traverse (No Adjustments) - Computes forward coordinates given occupied station, backsight station, angle and distance. Forward station then becomes occupied station. No adjustments are performed.

• Sideshots - Computes sideshot coordinates given occuppied station, backsight station, angle and distance. Occupied station remains the same.

• Auto Traverse Along a Line - Computes a series of forward points along the same bearing at a common distance.

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• Divide into Equal Segments - Divides the distance between two known points into equal segments, given the number of segments. May apply to a straight line, curve, spiral, or figure.			
• Inverse - Computes direction and distance information between two known points. In the case of a curve, computes curve data (arc length, central angle, etc.), given the P.C., P.T. and radius point. May also compute area at the end of inverse computations.			
• Auto Inverse - Inverses between a series of known points.			
• Curve Computations - Computes a point on curve, given the P.C., radius point and one of the other curve parameters. May also include computation of unknown curve parameters from known parameters, without computing coordinates.			
• Inscribe Curve Between Two Lines - Inscribes a curve between two lines, given the P.I., the bearings into and out of the P.I. and one other curve parameter.			
• Line Intersections - Computes coordinates of the intersection of two lines between two known points, given some combination of distance and bearing information. May include bearing/bearing, bearing/distance, distance/distance and bearing/bearing with offset. Sometimes has two distance/distance solutions, both a near and a far.			
• Coordinate Manipulation - Creates, stores, recalls, lists, or clears coordinates. May include the ability to add, or delete, descriptors/elevations at a later time. Applies to groups (sets, figures, etc.), as well as individual points. Some programs automatically store points to a file in order to prevent data loss.			
• Edit and Reprocess Coordinate Computations - Recomputes all desired coordinate computations after a change or correction is made. Often called batch processing or keystroke recording. Eliminates the need to recompute all related computations. Unusual in a COGO package.			
• Lot Summary - Computes the distance, bearing, curve information and area of a lot, given the lot corners. May also be accomplished using inverse. May include the printing of closing information and rounding of distances and bearings. Some programs generate reports, comparing individual areas to total area and individual lot frontages to total block frontages. If the values are within a specified tolerance, then rounding is done so that the sum exactly equals the parts. Useful for plat drafting and checking.			

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• Street Intersections - Computes the radius point, P.C. and P.T. of all four corners of a street intersection, given the centerline bearings, the corner radii and the widths of the intersecting streets. Usually includes straight/straight, curved/curved, or straight/curved street intersections. Sometimes includes an option to suppress computation of one or more of the corners.			
• Offset Intersections - Computes a point at a specified offset(s) from two intersecting lines, given the bearings into, or out of, the intersection point.			
• Point/Traverse Intersection - Computes the intersection of lines to a traverse, given known points and the direction of the lines between the points and the known traverse. The known traverse may be composed of straight line and/or curves. Sort of a multiple bearing/bearing intersection. Useful for computing the front lot corners, when the back lot corners and directions of the side lot lines are known.			
• Proportion Between Points - Proportions distances along a traverse made up of straight lines and/or curves. The last computed point is compared to the known end point and the closure error is proportioned among the individual distances. May include the ability to "hold" certain distances.			
• Point to Point Area - Similar to inverse with area, or lot summary. May include a curve, or spiral leg.			
• Rotate/Translate - Rotates a group of points, given an angular rotation and/or a new starting location.			
• Comment - Inserts user comments on the printout. Useful for instructions to field crews.			
• Cul De Sacs - Computes the radius point, P.C. and P.T. of all cul-de-sac curb returns, given the center point, main radius, curb radius and the width and bearing of the intersecting street. Often includes bulb, offset and knuckle cul de sacs.			
• Standard Templates - Creates, stores and recalls standard templates (figures, details, etc.) for placement at specified locations. Almost always includes the ability to rotate/translate and may include the ability to rescale and mirror the template. Useful for positioning standard building footprints.			
• Figure/Line, Curve, Spiral Inter. - Computes intersection points of a figure with a line, curve, or spiral, given a known point and direction.			

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- Predetermined Area - Computes the end point(s) of a line that will yield a user specified area of a lot. Usually includes parallel sides (rectangular lot) and hinged side (triangular lot), but may also include radial sides (cul-de-sac lot).
- Radial Stakeout - Computes the angles and distances to be turned to known staking locations, given the occupied and backsight station. Sometimes computes bearings and/or azimuths in addition to turned angles. May provide the capability to limit computations to those points within a user specified distance of the occupied point.
- Offsets from a Base Line - Computes the offset left/right and station of known points in relationship to a known baseline.
- Renumber - Renumbers a range of points, given the old point number range and the new starting point number.
- Proportionate Measurement - Computes the location of a point given 2 or four distances from 2 or 4 known points to the unknown point. Useful for locating lost corners.
- Circle thru Three Points - Computes the radius distance and radius point coordinates, given three points on a horizontal curve.
- Line Tangent to Circle - Computes the point of tangency for a point outside of a circle, given the radius point coordinates, the radius of the circle and the coordinates of the point outside the circle.
- Right of Way (Parallel Traverse) - Computes a left and/or right offset line paralell to a given baseline, or centerline. May compute more than one offset (curb, sidewalk, property) line in the same operation. May also include curves, as well as straight lines.
- Point to Point Angles - Computes clockwise and counter clockwise angles between three known points.
- Search - Provides for the capability to perform a point search by coordinates, point number, descriptor. Useful for finding points with common characteristics.
- Bearing Recall - Computes and recalls a bearing between two known points and uses it in coordinate computations. Useful for laying out parallel lines.
- Distance Recall - Computes and recalls a distance between two known points and uses it in coordinate computations. Useful for dividing distances between lots.

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- Integrated Math Computations - Integrates some math functions with the computation of coordinates. Usually used in conjunction with bearing and distance recall. For instance a user may be able to recall the bearing between points 1 & 3, add 90 degrees, then traverse a distance the same as from points 4 to 5, divided by 4. These should be integrated with coordinate computations and not a separate routine.

- Spiral Coordinates - Computes coordinates along a spiral curve, given some information about the spiral and some known coordinates.

- Spiral Parameters - Computes the remaining parameters of a spiral curve, given certain base information.

Plotting

Refers to plotting lines between points on a screen, printer, or plotter. Plotting elevations, contours, annotation and other descriptive information is a plus. In COGO packages, generally used as a visual check of computations and not used to produce finished drawings.

Tasks/functions to look for include:

- CRT, Printer or Plotter - Plots lines and/or points on a screen, graphics printer, or pen plotter. Usually requires user to scale, orient and develop a plot sequence before plotting is done. Usually plots point numbers and may provide some limited point and line annotation capabilities.

- Auto Plot/Scale to Screen - Computer automatically scales and orients the plot to the plotting surface. Useful for quick and dirty pictorials of previously entered data.

- Screen Plot as you Compute - Points and/or lines are plotted to the screen as they are computed. Some scaling and orientation is necessary.

- Zoom In/Out on Sections of Plot - Performs a screen blow up or reduction of sections of the plot by outlining desired section with a cursor.

- Window Sections of Plot - Similar to zoom in/out but requires user to specify the plot window by defining coordinate limits. Useful for obtaining hard copy output of sections of a plot.

- Load and Store Plot List - May store a plot sequence for later recall and replotting, or editing.

- Plot Contours - Interpolates and draws user specified contour lines between elevations. Usually not very automated and quite tedious.

- Plot Elevations - Plots elevations, in addition to point numbers and X Y coordinates.

Miscellaneous Prog. (Surveying)

Includes horizontal and vertical design computations, not generally found in COGO packages. Computations may or may not be stored. Sometimes used to generate design reports for stakeout, vertical curves, etc.

Tasks/functions to look for include.

- Radial Survey - The reduction of topographic raw survey data to coordinates. Sometimes integrated with traverse routine. May include reduction for a variety of field instruments and methods, including total station, top mounted EDM, two instrument and stadia surveys.

- Vertical Curves and Grades - Computes elevations and stations for parabolic vertical curves and straight line grades, given certain known characteristics, such as entry and exit grades, station interval, length of curve, etc. May include the computation of the high and low points, curve passing through a fixed point and non symmetrical curves.

- Baseline Stakeout - Computes stakeout deflections and distances for straight lines, circular curves and spiral curves.

- Section Division - Computes unknown section corners from known quarter, center, or other known points. May subdivide into 4, 16, 64 parts.

- Map Check w/Plot - Automatically draws unscaled sketch from map or property description bearings and distances. Usually computes area and closure error. Useful for checking record maps and property descriptions.

- Stadia Reductions - Reduces stadia notes to horizontal distance, vertical distance and elevation. When not integrated with coordinate computations, not much better than stadia tables.

- Coordinate Transformation - Converts between geographic position and state plane coordinates for various U.S. zones. Usually utilizes stored constants. May include Lambert, Transverse, Alaska Zones, Universal Transverse Mercator and Oblique Mercator projections.

- Resection - Computes occupied station from three, or more, known coordinates. Useful for stakeout.

- Coordinate Transfer From Other Programs - Provides coordinate compatibility and transfer from and/or to other programs. The most common examples are transfer with Hewlett Packard/Wild Volume C coordinate geometry, or AutoCAD's drafting program.

Wild Heerbrugg	Geodimeter	Cubic

- Legal Descriptions - Facilitates writing legal descriptions. May be as simple as a basic text editor, or as sophisticated as automatically recalling common legal description terms, such as "to the point of beginning", "thence along a line", etc. May also be integrated with coordinate computations, so that points may be entered and automatically converted to bearings and distances by the program.

- Line Layout From Random Traverse - Computes coordinates of points on a baseline, or property line, from known points on a random traverse, offset from the baseline. May also compute distance and angle from the random traverse points to the baseline and distance from the start of the baseline. Useful when field obstructions make it impossible to run the traverse along the intended line.

- EDM Slope Reduction - Reduces raw slope distances to horizontal distances, based upon zenith angle, EDM offset, height of instrument, target height, curvature and refraction constants, etc. When not incorporated with traverse or coordinate computations, is little more than an expensive calculator. Taping reduction may also be included.

- Celestial Observation - Computes the azimuth of a line from observation of the sun, or a star. Ephemeris data is often incorporated in the program and stored on disc.

- Field Angle Check - Reduces and computes the mean of multiple sets of angles from either a repeating or direction instrument. May also compute deviation from the mean of individual angles and the spread between angles. When not incorporated with traverse computations, is little more than an expensive calculator.

- Automatic Data Collection - Accepts and automatically reduces data from field data collectors. Providing reduction programs for specific brands of data collectors is much better than generic data collection packages, because they take advantage of the specific capabilities of each. May also provide two way communication out to the data collector for automatic staking purposes. See modules on data collection and automated stakeout for more information.

- Vertical Plotting - Provides limited plotting of cross sections or profiles from elevation information. Not intended as a full capability road design or earthwork program.

- Triangle Solutions - Uses geometry to compute the missing sides and angle of a triangle.

Wild Heerbrugg	Geodimeter	Cubic

		Wild Heerbrugg	Geodimeter	Cubic
Field Instrument	The ability of your electronic field instrument to track the target, compute and display distance/direction to stakeout point, communicate with the data collector, and calculate coordinates. Tasks/Functions to look for include.			
• On Board Computation	Usually, distances and directions are entered from the keyboard or uploaded from a data collector. Tracking and computation of relative stakeout values (direction, distance, etc.) is then performed. However, some instruments may be able to compute stakeout distance and direction from coordinates entered via the keyboard.			
• Number of Displays	Instrument displays all relevent stakeout data (angle to turn, azimuth, distance to point, coordinates of point, difference in coordinates to point, etc) simultaneously. The more displays, the better.			
• Tracking	Instrument tracks the reflector with instantaneous updates of distance. This is usually a coarse distance and is computed and displayed much faster than a distance taken during a control traverse. Some instruments track relative elevations and angles, as well. Measurement speed is important.			
• Countdown To Zero	Some instruments have countdown to zero capabilites that display a zero angle when the instrument is on line and a zero distance when the rodman is at the stakeout point. In other words, the angle to the line and distance to the stakeout point are tracked.			
• Beam Width	A wider measurement beam will allow the rodman to "wander" off line more, before the instrument loses the return signal. Usually specified as the angle between beam edges. The greater the angle, the better.			
• Time Out	Some instruments have time out of the beam restrictions. In other words, if the rodman is out of the beam for more than a specified period of time, the instrument will lose tracking and a new measurement will have to be initiated.			
• Display Difference	Computes and displays the angle and distance difference between the current point and the next point to be staked. An X and Y distance to the stakeout point may also be computed and displayed. Gives rodman clearer idea of where he should go next.			

Data Collector

Refers to the ability of the data collector to compute stakeout values from stored coordinates, upload them to the instrument and record as staked locations.

Tasks/Functions to look for include.

- Store/Recall Coordinates - Loads coordinates of known points into data collector memory for puposes of computation. May be transmitted to instrument for further computation. Also stores computed coordinates, such as "as staked locations".

- Coordinate Computation - As discussed previously, data collectors can perform many types of computations. Those related to stakeout include computation of stakeout directions and distances from known points, tracking computations (relative distances, directions and coordinates) and resection. Some even have programs designed to compute offset points from baselines. Useful in setting batter boards for building corners.

- Resection - Computes the occupied station by using triangular geometry and two or more known points. The greater the number of known points and the more distance/angle combinations possible, the better. May compute and record the accuracy (standard deviation) of the overall measurement and indicate the standard deviation of each resection point. Often called free station. Caution! The accuracy of your computation depends quite heavily on the geometry of your set up and the accuracy of each measurement so be aware of the math, before relying too heavily on the result.

- Two Way Communication with Instrument - Uploads information to the instrument and monitors intrument measurements during stakeout.

- Record "As Staked Locations" - Records the location actually staked in the field. May be recorded as absolute coordinates, relative coordinates (delta Z = cut or fill), distance left/right and in/out, direction and distance from occupied station, etc.

Wild Heerbrugg	Geodimeter	Cubic

Auxillary Equipment

Refers to electronic equipment that help rod and instrument man communicate.

- Radios - If you've ever tried to yell instructions to a rod man against a strong north wind, then you know two way radios can be important. Hand signals are a substitute, but not as productive.

- Receivers/Transmitters - Refers to one way communication. Rodman may have an electronic display which receives stakeout values from the instrument, or a radio type voice receiver. Transmitter is at the instrument.

- Tracking Lights - Device that emits a light from the instrument to the rodman. Usually changes color, depending upon whether you are left, right, or on line. Sometimes blinks at different frequencies as you get closer to exact line.

- Miscellaneous Equipment - Refers to staking aids, such as special targets, staking tripods, etc.

Wild Heerbrugg	Geodimeter	Cubic

Data Collection Checklist

Function	Wild Heerbrugg	Geodimeter	Cubic
General Functions Refers to general capabilities and functions of the data collector. These may include:			
• Measurement Sequences - Number of different sequences with which a user may collect data. User may select from built in sequences, or define his own. A sequence refers to the order in which measured and observed data (slope distance, horizontal angle, vertical angle, target height, etc.) is collected.			
• User Programmable Prompts - User may define his own prompts. Generally allows built - in prompts to be modified to user terminology, or the addition of prompts not built - in.			
• One Button Transfer - Refers to the transfer of all measured data (slope distance, horizontal angle, vertical angle) to the data collector at the touch of one button. If that button is on the instrument, the data collector can be hung on the tripod, leaving the operator's hands free.			
• Manual Data Entry - Allows measured data to be entered manually from the keyboard. Desirable if field instrument is not electronically linked to the collector.			
• Editing - Corrects and changes collected data. Some retain both the original and corrected data. This may be required from a legal standpoint.			
• Search - Finds data by searching for a particular known point number, angle, distance, code, etc.			
• Erase Edited Data - Same as editing, only original data is destroyed. This may not be desirable. Some data collectors give you the option to erase or keep original data.			
• Set Instrument Parameters - Characteristics of different field equipment (EDM offset, prism offset, type of EDM, type of theodolite, etc.) may be input. These parameters are then reflected in all data reduction computations. Some of these may be set in the instrument.			
• Set Measurement Parameters - Sets the characteristics of measured data (curvature & refraction, sea level correction, pressure/temp, etc.). These parameters are then reflected in all data reduction computations. Some of these may be set in the instrument.			
• Set Angle & Dist. Toler. - Sets angle and distance tolerances for multiple measurements. The user is then warned when the measurement does not meet tolerances.			
• Direct or Repeat. Angles - Records angles with either a direction or repeating instrument.			

- Multiple Angle Sets - Records multiple turned angles for later reduction by either the data collector, or an office software package.

- Automated Plot Codes - Numeric codes, which will later be decoded by the office software to plot a symbol, or a line between points may be entered.

- Time Stamps Data - Provides some method of automatically recording the time and date of measurements.

- Records Multiple Jobs - Records data for more than one project at a time. Should be recorded in separate, designated files.

Data Recorded

The ability of the data collector to record measured and observed data. The following may be recorded.

- Project Reference - Descriptive information for each project. May include file name, project name, client name, field crew, etc.

- Instrument Parameters - See Set Instrument Parameters above.

- Measurement Parameters - See Set Measurement Parameters above.

- Descriptive Notes - Text may be entered to further describe points, conditions, etc.

- Point Code - An alpha or numeric code designed to describe the point being measured. Usually, decoded by the software and translated into a descriptive note, and/or plotted symbol.

- Point No. - Point number recorded with measured data.

- Occupied Station - The instrument station from which measured data is taken.

- Ht. Instrument - The vertical distance from the instrument center ground point to the horizontal axis of the telescope.

- Ht. Target - The vertical distance from the measured ground point to the center of the reflector/prism.

- Slope Distance - The measured slope distance from the center of the instrument to the reflector.

- Horizontal Angle - The measured horizontal angle between the backsight and target.

- Vertical Angle - The measured vertical angle between the target and either the vertical axis (zenith angle), or the horizontal axis (vertical angle) of the instrument. Sometimes referred to as zenith angle.

Wild Heerbrugg	Geodimeter	Cubic

Duplication of Data

The ability of the data collector to duplicate repetitive data automatically. Very important in determining overall ease of use and field productivity. The following may be duplicated.

- Point Code - Automatically repeats the last point code, unless told differently by the operator.

- Point No. ± 1 - Automatically increments the point number by one, until told differently. Sometimes decrements number by one.

- Ht. Target - Automatically repeats the last target height, until told differently.

Built-In Programs

The ability of the data collector to act as a calculator, or computer. Refers to built in "turn-key" programs provided by the manufacturer. Some of these calculations may be performed by the field instrument and the results transmitted to the data collector.

- Traverse - Records backsight, occupied and foresight station data in such a way that the data collector and/or an office computer may compute traverse coordinates. Optionally, may compute and record coordinates and compute closure error.

- Topography - Records backsight point, occupied station and sideshot target data in such a way that the data collector and/or an office computer may compute coordinates. Optionally, may compute and record coordinates. Some record both measured data and reduced coordinates. Useful for topographic surveys.

- Stake Out - Allows the operator to stake out points from coordinates stored in the data collector. Data collector calculates angle and distance, based upon known coordinates of the backsight point, occupied station and stakeout point. May provide two way communication of distance and angle to stakeout point, record "as staked coordinates", compute cut/fill, etc. Sometimes referred to as "setting out". Discussed in more detail in Module 4.

- Inverse - Computes distance and direction information between two points of known coordinates.

- Resection - Computes the occupied station by using triangular geometry and two or more known points. The greater the number of known points and the more distance/angle combinations possible, the better. May compute and record the accuracy of the measurement. Useful for stakeout applications (see Module 5 for a more complete definition).

- Remote Elevation - Computes the elevation of an inaccessable target point above/below a measured ground point.

- Calculate Coordinates - Computes the coordinates of a point by its relative position to a known point. Uses measured data.

Wild Heerbrugg	Geodimeter	Cubic

- Store Coordinates - Records, as well as computes, coordinates.

- Input Known Parameters - Refers to keyboard input of reference information, such as back azimuth, starting coordinates, etc. this information is then used by other built in programs to perform computations.

- Display Raw Data - Provides for the review of raw measured and observed data.

- Collimation Correction - Determines the field instrument's collimation error and automatically applies it to measurements.

- Formated Output to Printer (Without Aid of Computer) - The ability to print formatted readable field notes directly to a printer, without the aid of a computer. Typically, most data collectors provide an RS-232C interface and transmit a computerese type "COMS" output to the printer. A formatted output takes this one step further and identifies all measurements and observations with english headings, such as horizontal angle, slope distance, etc.

Programmability

The ability to change or program, either the recording order of measured data (see measurement sequences above) or the function of the data collector.

- Program From Keyboard - Manually programmed from the keyboard of the data collector. Usually refers to changing measurement sequences only.

- Download From Computer - Programming from an office computer may be downloaded to the data collector.

- Number Of Programs That Can Be Stored - Usually, there are some memory limitations that restrict either the number and/or size (number of bytes) of additional programs that can be stored in the collector.

Wild Heerbrugg	Geodimeter	Cubic

Drafting Checklist

Linework

The ability to plot a variety of line types. Includes, the number of standard choices and capability to create additional line types. May include the ability to plot lines by specifying ranges of consecutive or blocks of non consecutive points. The ease with which this can be done is extremely important.

Optionally, may include the ability to graphically represent ground elevations, by plotting point elevations, contours, cross sections and profiles. While most drafting programs have limited 3D capabilities, they are primarily designed for 2 dimensional plan views. Any extensive 3D capabilities are usually reserved for specialized software, such as topographic modelling, road design and earthwork packages.

Tasks/Functions to look for include:

	Wild Heerbrugg	Geodimeter	Cubic
• <u>Standard Types</u> - Number of standard line types which a user may select. For example solid, dashed, centerline, etc.			
• <u>User Definable Types</u> - Number of line types which a user may create and store for later use. For example fence line, railroad tracks, etc.			
• <u>Spec. Repeat Pattern Lengths</u> - Can a user vary the repeat pattern length of line types? For example, short, or long, dashes.			
• <u>Plot Range of Points</u> - Plots lines between a range of consecutive points. Useful for automatically plotting similar line types with similar attributes.			
• <u>Plot Sets of Points</u> - Automatically plots a set (group, figure, layer etc) of non consecutive points. These sets are usually created in coordinate geometry. Useful for plotting similar line types, with similar attributes. For example, a boundary, centerline, R/W line, or lot perimiter may be described as a set and plotted with one command.			
• <u>Cross Hatch Areas</u> - Highlights selected areas of the plot with cross hatching, shading, or special symbols.			
• <u>Plot Scaled Lines</u> - Uses a digitizer to plot from a scale, rather than between coordinates. Useful for plotting scaled easement lines.			
• <u>Digitize Existing Drwgs.</u> - Existing maps may be digitized and stored for later replotting. A plotter may have some limited digitizing features to orient existing maps on the plotter bed, but this usually requires a digitizing table and puck (digitizing site, with numeric keypad). May include the ability to <u>trace contours and curves</u>, as well as digitize the end points of straight lines.			

* Calculate & Plot Contours - Calculates and plots user specified contour intervals between spot elevations. This can laboriously proceed on a point by point basis or be automatically done by the program.

* Draw Paralell Lines - Draws a line paralell to another line, without computing the end point coordinates. Useful for plotting easement and other lines that do not require coordinates to be staked in the field.

* Draws Lead In Arrows - Plots lead in arrows from annotation, or notes that are cast off from a line.

* Instant CRT Plot - Plots a line sketch on the screen as points are being computed or the plot file is being developed. Useful for checking your work as you proceed.

Annotation

The ability to automatically annotate lines or points with their parametric values. The values are computed by the program and placed at user specified locations. Tasks/functions to look for include:

* St. Line Parameters - Includes bearing/azimuth and distance.

* Curve Parameters - Includes arc length, chord length, tangent length, radius, central angle, deflection angle, etc.

* Point Parameters - Includes X Y Z coordinates, descriptors, point numbers, etc.

* Annotation Locations - The user specified position of the annotation for straight lines, curves and points. Often set up by menu selection, before the plot sequence is entered. Usually provides a choice of two or more locations. When your choice doesn't fit, program automatically puts information in a curve table, for later plotting. Some programs provide the capability to specify an alternate location. Digitizer based programs are, generally, more flexible than keyboard based programs.

* Size - User may specify the size of annotation by either an absolute value or a value relative to scale.

	Wild Heerbrugg	Geodimeter	Cubic
Calculate & Plot Contours			
Draw Paralell Lines			
Draws Lead In Arrows			
Instant CRT Plot			
Annotation			
St. Line Parameters			
Curve Parameters			
Point Parameters			
Annotation Locations			
Size			

Symbols/Figures

The ability to select, position and create point symbols and special figures. Building footprints, trees, manholes, etc. are examples. Using a table digitizer to create these is much faster than using a keyboard to enter coordinates or a plotter digitizer to digitize locations.

Tasks/Functions to look for include:

* <u>Standard</u> - Number of standard symbols/figures provided by the program. For example, point marks, tic marks, circles, squares, triangles, trees, etc.

* <u>User Definable</u> - Number of symbols that may be defined and stored for later use.

* <u>Size</u> - User may specify size of symbols/figures by either absolute values or values that vary with scale.

* <u>Mirror Image Symbols/Figures</u> - Flops over, or mirrors, symbols and figures. Useful for plotting standard building footprints.

* <u>Specify Rotation</u> - Specifies the rotation angle about a point of the symbol or figure.

Keyboard Text

Inputting, positioning and plotting special text, such as notes, street names, lot numbers, block numbers, etc. Different than annotation, as all text entry is manually input from the keyboard. User may vary the <u>size, style and slant</u>. <u>Location</u> is chosen by coordinate positions or with a digitizer. Some programs allow the user to plot a rectangular box where text is be located (includes annotation). Allows user to get a quick look at the plot and decide whether everything looks okay before a final drawing is attempted. May be done on the screen or plotter. Using a table digitizer to locate text is best.

Miscellaneous Functions

Includes program wide functions, not specific to annotation, keyboard text, or linework.

Tasks/functions to look for include:

* <u>Vary Text Size With Scale</u> - Selects text and/or annotation size in proportion to scale. When the plots scale is changed, all text is automatically changed to fit.

* <u>Vary Text Ht./Width Ratio</u> - Elongates, or squashes, text.

Wild Heerbrugg	Geodimeter	Cubic

Feature	Wild Heerbrugg	Geodimeter	Cubic
• Auto # Lots/Blocks - Program automatically increments lot numbers once location is chosen. When used in combination with a digitizer, or with a program that automatically places the number at the center of the lot, this can be a very powerful tool.			
• Automated Legal Descriptions - Facilitates plotting legal descriptions. May be as simple as a basic text editor, or as sophisticated as recalling common legal description terms, such as "to the point of beginning", "thence along a line", etc. May also be integrated with coordinate geometry, so that points may be entered and automatically converted to bearings and distances by the program.			
• Line & Paragraph Editors - Allows text corrections on a line by line or paragraph by paragraph basis. Paragraph editor's are usually more flexible, because they contain some word processing functions and automatically reformat paragraphs.			
• Listing & Editing Plot Sequences - Lists and corrects plot files (sequences). May be as tedious as changing every line, or as simple as making one change and having it reflected in the rest of the file. Some programs can search and replace plot instructions. For example: "search for all dashed lines and replace them with solid lines". This can be a very powerful editing tool. Copying standard plot sequences from one part of the file to another, can also be very useful.			
• Auto Replot Entire Drwg. - Automatically replots the entire drawing. Useful when changing scales and orientation. Most programs can easily replot lines, points and annotation, but special text, north arrows and tables are sometimes manually located after the drawing is complete.			
• Orient/Rotate Plot - Orients and rotates the location of the plot on the plotting surface. Usually requires a rotation point and X Y location from a corner of the plot surface, plus a direction of rotation, scale, overall plot dimensions, etc. All annotation and text should be automatically re-oriented to read properly.			
• Window Section of Plot - Isolates and plots a section of the plot file.			
• Pens Supported - How many pens does the program support. The more pens it supports, the less often you have to manually change pens.			

INDEPENDENT EVALUATION PLAN
FOR THE
MARKET INVESTIGATION
OF THE
AUTOMATED INTEGRATED SURVEYING INSTRUMENT (AISI)

US ARMY MATERIEL COMMAND

BY

JOSEPH A. ANDRESE

SEPTEMBER 1987

HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND

Disposition Instructions

Destroy this plan when no longer needed. Do not return to the originator.

Neutral Language Statement

The word "he," when used in this plan, represents both the masculine and feminine genders, unless otherwise specifically stated.

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005 – 5055

REPLY TO
ATTENTION OF
AMSTE-EV-S (70-10p)

17 SEP 1987

MEMORANDUM FOR: Commander, U.S. Army Belvoir Research, Development and Engineering Center, ATTN: STRBE-JCT, Fort Belvoir, VA 22060-5606

SUBJECT: TECOM Independent Evaluation Plan for the Market Investigation of the Automated Integrated Surveying Instrument (AISI)

1. Subject document is forwarded for information and use.

2. The points of contact at this headquarters are Mr. Joseph A. Andrese, AMSTE-EV-S, amsteevs@apg-1.arpa, AUTOVON 298-5221/5222 and Mr. Richard H. Britton, AMSTE-TE-T, amstetet@apg-1.arpa, AUTOVON 298-3766/3640.

3. TECOM - Providing Soldiers the Decisive Edge.

FOR THE COMMANDER:

Encl

HARRY J. PETERS
Technical Director

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Comdt, USAES, ATTN: ATZA-CD, ATZA-TE
Dir, Def Mapping Sch
Cdr, USALEA, ATTN: LEI
Cdr, TROSCOM, ATTN: AMSTR-L, AMSTR-PWL, AMSTR-QE, AMSTR-MS
Cdr, USACAC, ATTN: ATZL-TIE
Cdr, USALOGC, ATTN: ATCL-M, ATCL-TE
Cdr, CECOM, ATTN: AMSEL-ME
Cdr, MRSA, ATTN: STEAP-MT
Cdr, USASC, ATTN: ATZH-CDM, ATZH-TS
Cdr, BRDEC, ATTN: STRBE-T, STRBE-Q, SLCHE-ME, AMCPM-TSS STRBE-JCT
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APPENDICES

INDEPENDENT EVALUATION PLAN
FOR THE
MARKET INVESTIGATION
OF THE
AUTOMATED INTEGRATED SURVEYING INSTRUMENT (AISI)

1. SYSTEM DESCRIPTION

The Automated Integrated Survey Instrument (AISI) is an electronic surveying system intended to supply the military surveyor with a single device with which to achieve all functions formerly carried out with theodolites and distance measuring devices. With the fielding of the AISI, the Surveying Equipment, Distance-Measuring, Medium Range (SEDME-MR) and the Wild T-2 Theodolite will be deleted from the inventory. The AISI will automatically perform horizontal and vertical angle measurement, horizontal and vertical distance measurement, and slope and zenith distance measurements. It has an on-board microcomputer to automatically calculate the above functions at the push of one or more buttons by the operator. The results of these functions are then displayed on the instrument panels, and can concurrently be routed to a portable data collector for retention and later use in the office. The data stored in the collector is transferred to an external microprocessor for direct printing by a printer and/or plotter, or refinement with the use of commercial surveying software programs.

2. BACKGROUND

2.1 The requirement for the AISI was identified in the Topographic Support System (TSS) Required Operational Capability (ROC) (Reference 1) in 1978; however, at that time only one manufacturer was known to produce such an instrument and it cost approximately 50 thousand dollars. The decision was made to postpone procurement of the AISI, but not to delete the requirement. The deficiency was again identified in the May 1983 Combat Support, Engineering and Mine Warfare, Mission Area Analysis, and the market surveillance now shows that commercial AISI's are available.

2.2 The U.S. Army Engineer School requested that the TSS ROC be authenticated as the approved requirement document for the AISI. The approved Operational and Organizational (O&O) Plan (Reference 2) describes the need for AISI by all elements of the topographic survey units, topographic and intelligence teams, and engineer construction units.

2.3 The survey equipment currently in use by survey units requires that all raw data be collected by conventional manual means, which is very time consuming, prone to errors, and causes survey projects to be completed in weeks and months, instead of the required hours, days, and weeks defined in the May 1983 Combat Support, Engineering and Mine Warfare, Mission Area Analysis.

2.4 A Market Surveillance was conducted to identify industry's technical capabilities and capacities to demonstrate user identified requirements, and provide information which was needed in order to conduct a more thorough market investigation. The market surveillance has shown that an NDI - Category A (off-the-shelf) acquisition program is feasible. Contract award is scheduled for the 4th Quarter FY 88. A Market Investigation is now underway to identify the systems in existence which demonstrate the military mission requirements as specified in the AISI O&O. The Market Investigation involves the gathering of test data from commercial AISI manufacturers and AISI users, and evaluations conducted by the Government.

2.5 The Milestone I/III, In-Process Review (IPR) is scheduled for the 2nd Quarter FY 88. The Technical and the User Independent Evaluation Reports (IER's), along with the generic commercial market specification will be used as the basis for type classification of a generic AISI specification or purchase description. Important milestones in the AISI acquisition program are contained in Appendix B.

3. OBJECTIVES

The Independent Evaluation Plan (IEP) is intended to:

- Provide a plan for the TECOM technical independent evaluation of the AISI during the Proof of Principle phase of the Acquisition Cycle.

- Provide an outline of the methods which will be used to assess the extent that AISI candidates demonstrate requirements of the TSS ROC (Reference 1), O&O Plan (Reference 2), and applicable military standards.

- Describe the methods which will be used to determine whether AISI is ready to enter into the Production and Deployment Phase of the acquisition cycle.

4. SCOPE

4.1 This IEP includes the evaluation issues, methodologies, and data requirements for evaluation of AISI. The evaluation will assess the technical and environmental performance, compatibility/interoperability, reliability, logistic supportability, human factors, safety, physical characteristics, and surveying operations capabilities. Results of the individual characteristics assessments will be used to determine the military utility of the AISI.

4.2 All test data and data from technical documentation, regardless of the sources, will be considered in the evaluation in compliance with the Single Integrated Test Concept (SITC). Government test and evaluation organizations involved with Technical Testing of the AISI include the U.S. Army Test and Evaluation Command (TECOM), the Belvoir Research, Development, and Engineering Center (BRDEC), and an independent engineering services contractor appointed by BRDEC. Testing during the Market Investigation will be conducted in accordance with Government reviewed and approved test plans.

5. OPERATIONAL ENVIRONMENT

5.1 Threat. There are no major survivability and endurance goals that require validation. No attempt is being made to nuclear harden the AISI, or protect it from NBC effects since it is an off-the-shelf commercial product. Testing will identify the effects on survivability and endurance of varying environmental conditions, high-altitude electromagnetic pulse (EMP), and chemical-biological decontamination procedures.

5.2 Climatic. The AISI will be operated in the ambient temperature range from -5°F to 120°F. The AISI will be expected to be used in the Hot, Basic, and Cold climatic design types as defined by AR 70-38 (Reference 3), Table 2-1.

5.3 Transportability. The AISI will have the same transportability characteristics as present transportable (mobile) survey instruments. Field parties normally travel in 5/4-ton CUCV vehicles, survey company personnel in 1/4-ton trucks, and the survey section of the Topographic Support System in a 5-ton tractor vehicle.

5.4 Environmental Constraints. Certain environmental conditions, such as air drop, bounce, fungus, resistance, severe temperature, and military oriented protective posture evaluation, may result in the identification of operational constraints in severe environments.

6. CRITICAL [redacted]

6.1 Does AISI meet the [redacted]* for topographic and construction surveys as specified in the AISI O&O Plan and the Topographic Support System ROC, during day and night operations? The following characteristics will be included:

a. Minimum and maximum range

b. Horizontal, slope, and zenith distance measurement accuracy

c. Horizontal and vertical angle measuring accuracy

d. Optical capabilities

6.2 Does AISI meet the mission [redacted] transportation in all the expected environments, including nuclear high altitude electromagnetic pulse (EMP) and can the AISI be decontaminated?

6.3 Are the measured [redacted], and available for transfer and is the AISI [redacted] microprocessors for further production of survey functions?

6.4 Do the [redacted] interface with AISI to [redacted]?

6.5 Does the AISI meet the established [redacted] and, if not, what impact will this have on mission requirements?

6.6 Does the logistics supportability plan for the AISI system (AISI with support equipment and software) satisfy mission needs and what is the impact on the overall logistics supportability if any of the elements listed below are not met?

a. End-Item Requirements

b. Supply Support

c. Technical Data/Publications

d. Support and Test Equipment

e. Manpower and Personnel, Training and Training Devices

f. Transportation and Handling

6.7 Can the AISI meet [redacted] (elements of HFE, RAM, ILS, New Equipment Training (NET), and personnel safety/health hazard) when operated and maintained by MOS-qualified, NET-trained, experienced personnel wearing clothing and equipment appropriate for the operating and maintenance environmental conditions?

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6.8 Have the [redacted] associated with AISI operation, maintenance, transportation, and storage been controlled to an acceptable level?

7. OTHER TECHNICAL EVALUATION ISSUES

7.1 Does the AISI meet the MIL-STD-461B requirements for electromagnetic interference/[redacted]

7.2 Does AISI meet the [redacted] such as weight, size, and rigidity?

7.3 Is the [redacted] for reliable AISI operation in compliance with the operational mode summary/mission profile?

7.4 Is the AISI [redacted] with which it is required to interface?

8. MILITARY TEST AND EVALUATION PERSONNEL PARTICIPATION

Central to the doctrine of structured technical testing is the use of experienced Military Operational Specialty(MOS)-qualified soldiers. Soldier/operator, maintainer, test, and evaluation (SOMTE) personnel must use the fully functional AISI system in the performance of tasks in accordance with the Operational Mode Summary/Mission Profile (OMS/MP). SOMTE personnel with the proper MOS(s) will participate in various portions of testing, to include the human factors aspects of operation and maintenance. However, if it is not possible to use SOMTE personnel during the Market Surveillance testing, then available test personnel will be used to validate whether the proper MOS's have been established and whether the manuals are adequate.

9. MANPRINT

The MANPRINT evaluation will be based on data from testing in its domains that are addressed by human factors engineering, system safety, and integrated logistics support during the Market Investigation of the AISI. Major test incidents occurring in these areas will also be designated as MANPRINT failures. A MANPRINT statement will appear in the Independent Evaluation Report (IER) which will be available prior to the next scheduled IPR.

10. ENVIRONMENTAL DOCUMENTATION

Before any Government testing on AISI can begin, the environmental documentation requirements described in Appendix C must be provided.

11. ALTERNATIVES

Three different models of AISI's will be tested during the Market Investigation. The models are not being tested for production competition purposes. Test results will be used to verify the availabilty of commercial systems to satisfy the military requirements and to use the test results to establish a basis for a generic purchase description based on state-of-the-art characteristics. The models that will be tested during the Market Investigation are:

- Cubic Precision, model T1A
- Geodimeter Inc., System 440
- Wild Heerbrugg, model T2000

12. MODELS AND SIMULATIONS

No models or simulations will be used in the AISI evaluation. A checklist described in Appendix A, will be used to summarize the characteristics of the AISI candidates. The purpose of using the checklist will not be to indicate which of the three candidate systems is best, but will be used to show the degree to which the military requirements can be satisfied by commercial candidates. The results of the checklist will be used to determine the best characteristics that are available for specifying in the preparation of the generic purchase description.

13. SYSTEM EVALUATION PLAN

13.1 The plan for the AISI Market Investigation evaluation consists of making comparisons between AISI test and analysis results and the military requirements specified in the TSS ROC and the O&O Plan. The Surveying Electronic Distance-Measuring Equipment (SEDME) Specification (Reference 4) and FM 5-105 for Topographic Operations (Reference 5) will also be used as additional sources of military requirements. The results of the investigation will be used to answer the technical evaluation issues needed in preparation for making decisions relevant to the Milestone I/III In-Process Review (IPR). The purpose of the IPR will be to type classify the generic purchase description for a commercial AISI system.

13.2 Three surveying instruments (one sample from each manufacturer) will be tested. The Test and Evaluation Master Plan (TEMP) (Reference 6) is being prepared by BRDEC in coordination with the Test and Evaluation Working Group (TIWG). The TEMP will describe the extent, length of time, and the locations of the Market Investigation testing. The engineering services contractor's test plan (Reference 7) was prepared and describes the testing planned to be conducted during the Market Investigation. Both the TEMP and the engineering services contractor's test plan are being reviewed by TECOM and both will be used to determine adequacy of test data needed for the Technical Evaluation. Testing will be conducted in the laboratory environment at the engineering services contractor's facilities, in simulated environmental chambers, and in the field at BRDEC's Engineering Proving Grounds at Fort Belvoir, Va. Testing will include technical performance and simulated environmental (high and low temperatures, solar radiation, humidity, rainfall, shock and vibration, magnetic environment, sand and dust). Also, electromagnetic interference (EMI), power consumption, battery life, Human Factors Engineering (HFE), Reliability, Maintainability, Infrared Radiation, and Safety tests will be conducted. Field operational testing will consist of surveying operations which include triangulation, traverse, and geodetic leveling. Incidents that occur throughout testing should be reported similar to Test Incident Reports (normally provided by TECOM installations during tests). Final test reports from the engineering services contractor will be used as data sources for evaluation.

13.3 The Technical evaluation issues, criteria, data requirements, and evaluation methodology are presented below.

13.3.1 Does AISI meet the performance requirements for topographic and construction surveys as specified in the AISI O&O Plan and the Topographic Support System ROC, during day and night operations? The following characteristics will be included:

a. Minimum and maximum range

b. Horizontal, slope, and zenith distance measurement accuracy

c. Horizontal and vertical angle measuring accuracy

d. Optical capabilities

13.3.1 1 Criteria

a. The AISI is required to perform the following mission profile: To provide horizontal coordinates, elevations, azimuths, and hard copy output using field survey methods at the accuracy required for accomplishing the theater geodetic, topographic, construction, and artillery and fire missions.

b. AISI equipment must have illuminated reticle for night observations.

c. Topographic characteristics desired are as follows:

(1) Distance measuring capabilities: range of from 2 meters to 14 km (O&O is expected to change to 7 km) with modular capability to 20 km and with a digital output to 1 mm with an accuracy of +/-5 mm and +3 ppm.

(2) Tracking mode with a response time of 1 second or less.

(3) Angle-measuring accuracy: electronic incremental reading of horizontal and vertical readout with an accuracy of 1.0 seconds with a measuring time of less than 0.5 second.

(4) Optical capabilities: illuminated reticle for night observations; telescopic magnification of 30 to 40 power erect image for angle measurements; minimum focus of 2 meters or less for angle measurements.

d. Construction Survey Capabilities. The construction device should have the same capabilities as the topographic device with the following exceptions:

(1) Range: from 2 meters to 2 km with a digital output in feet or meters readable to 1 mm or 0.005 foot.

(2) Angle measurement: electronic incremental reading of horizontal and vertical readout with an accuracy of 30 seconds with a measurement time of less than 0.5 second.

13.3.1.2 Data Required

a. Range and range accuracy. Minimum, in-between, and maximum range measurements, with a statistically sufficient number of readings to characterize the horizontal, slope, and zenith distance measurement capability and accuracy in day and night conditions for the required survey operations.

b. Distance measurement time. Statistically sufficient number of time measurements to characterize the time required for distance measurements at various ranges in day and night conditions for the required survey operations.

c. Horizontal and vertical angle measuring accuracy. Statistically sufficient number of angle measurements to characterize vertical and horizontal angle measuring accuracy in day and night conditions.

d. Field operational surveying data to verify topographic and construction survey capabilities.

e. Optical characteristics to include verification of telescopic magnification and focusing for maximum and minimum ranges in day and night conditions, resolution, reticle lines, stadia lines, automatic, optical plummet, and stadia distance.

f. Degree of stability.

g. Influence of weather, including the following conditions: excellent atmospheric, dust, operation over hot sun-heated surfaces, wind, rain, and fog. Testing under various weather conditions will be designed to include excellent (around 30 km visibility), average (around 15 km visibility), and poor (around 3 km visibility).

h. Influence of varying light conditions, including full sun, cloudy, and night.

i. Survey closure errors in accuracy ratio (error per unit of distance surveyed).

j. Description of each test exercise, including the date, time of day, light conditions, weather, slope of terrain, and vegetation.

13.3.1.3 Evaluation Methodology

a. Performance test data acquired under controlled laboratory conditions and field operational functional test data will be used for the evaluation. Mean and standard deviation estimates for range measurements, range accuracy, distance measurement time, angle measurement accuracy, and survey closure errors are to be presented in tabular form and graphs (when appropriate). Estimated results will be compared to the recommended and required values.

b. The influence of varying degrees of visibility/weather, environment, light, and terrain on measurements will be assessed for impacts to the successful completion of topographic and construction surveying missions.

13.3.2 Does AISI meet the mission requirements for operation, storage, and transportation in all the expected environments, including nuclear high altitude electromagnetic pulse (EMP) and can the AISI be decontaminated?

13.3.2.1 Criteria

a. Ambient temperature range of -5 Deg F to 120 Deg F.

b. The AISI will be expected to be used in the Hot, Basic, and Cold climatic design types as defined by AR 70-38, Table 2-1, and MIL-STD-210B.

c. The AISI will have the same transportability characteristics as present transportable (mobile) survey instruments. Field parties normally use 5/4-ton CUCV vehicles, 1/4-ton trucks, and 5-ton tractor vehicles for conducting surveying operations.

13.3.2.2 Data Required

a. AISI theodolite measurements of range, range accuracy, measurement time, and angle measuring accuracies will be measured after each environmental subtest, as indicated in Table 1 of the engineering services contractor's test plan (Reference 7). A fungus test should be included in the test design.

b. Effects on survivability and endurance of varying environmental conditions, to include high-altitude electromagnetic pulse (EMP) and chemical-biological decontamination procedures.

c. Functional performance after being submitted to climatic conditions which simulate the Hot, Basic, and Cold climatic design types as defined by AR 70-38 (Reference 3), Table 2-1.

d. Functional performance after shock and vibration testing that simulate similar transportability in 5/4-ton CUCV vehicles, 1/4-ton trucks, and a 5-ton tractor vehicle, air drop, and loose-cargo bounce.

e. Functional performance date for the AISI equipment should be obtained for operation in the natural climatic environments of the Cold Regions Test Center, Alaska, and the Tropic Test Center, Panama, during First Article Test and prior to materiel release.

13.3.2.3 Evaluation Methodology. Any structural or functional performance degradation will be analyzed to determine effects of the various environments on AISI mission-related performance.

13.3.3 Are the measured data automatically calculated, displayed, stored, and available for transfer and is the AISI compatible with software and external microprocessors for further production of survey functions?

13.3.3.1 Criteria.

a. Calculation functions:

(1) Automatically performs horizontal and vertical angle measurements, horizontal distance measurement, and slope and zenith distance measurements.

(2) Preprogrammed field calculations and storage.

(3) Built-in corrections for curvature, refraction, and slope.

(4) Ability to compensate for eccentricity of the instrument.

b. Data storage and display functions:

(1) 60-kilobyte memory.

(2) Alphanumeric keyboard.

(3) 16-column display.

(4) Minimum operating time of 16 hours.

(5) Data storage and retention of 1,500 hours.

(6) Direct data recording and dumping.

(7) Ability to store and lay out precomputed distances.

(8) Ability to lay out precomputed right/left deflection angles.

(9) Capable of measuring and layout of vertical angles, zenith distance, and percent of slope.

(10) LCD display readable in daylight or dark.

c. Data transfer and compatibility with microprocessors and software designed for processing of surveying functions:

- RS232/V24 interface to computer system.

13.3.3.2 Data Requirements

a. Calculation functions: data to assess horizontal and vertical angle measurements, horizontal distance measurements, and slope and zenith distance measurements. The following surveying operations and the associated data are required:

(1) Known baseline measurement: measure distance (EDM).

(2) Differential Leveling: take level readings, horizontal readings, distance readings (EDM), distance readings (stadia), and vertical readings.

(3) Plane Traverse: measure distance, elevations, azimuths, starting coordinates.

(4) Preliminary Location Survey (Road or Airfield) (Planetable Survey): measure distance, azimuth, establish control points.

(5) Final Layout (Roads and Airfields) (data from initial location): perform radial shots, establish control points.

(6) Building and Utility Set Preliminary Survey: distance, control point, and azimuth.

(7) Building and Utility layout: measurements to compute building layout, better board, location and level, utility, and line staking.

(8) Solar Observation: measure direct/reverse angles.

(9) Astronomic Observation (Star Shot): measure direct/reverse angles.

(10) Known Baseline: measure distance and validate instrument accuracy.

(11) Maximum range (EDM): measure distance.

b. Documentation which describes preprogrammed field calculations and storage capabilities; built-in corrections capabilities for curvature, refraction, and slope; ability to compensate for eccentricity of the instrument; data storage and display functions, to include 60-kilobyte memory, alphanumeric keyboard, 16-column display.

c. Test data to verify that the following capabilities are available with the AISI system: minimum operating time of 16 hours; data storage and retention of 1,500 hours; direct data recording and dumping; ability to store and lay out precomputed distances; ability to lay out precomputed right/left deflection angles; capable of measuring and layout of vertical angles, zenith distance, and percent of slope; direct data recording and dumping; LCD display readable in daylight or dark; data transfer and compatibility with microprocessors and software designed for processing of surveying functions to include the RS232/V24 interface to computer system.

13.3.3.3 Evaluation Methodology

a. Data storage, retrieval, and transfer for processing will be evaluated using structured performance test data and operational field test data. Calculated parameters, such as distances and angles, will be monitored on the visual display, stored, and made accessible for transfer to other equipment for further processing.

b. The COGO Checklist in Appendix VII of the engineering services contractor test report (Reference 7) will be used as a guide to evaluate the required storage, retrieval, and data transfer functions of the AISI.

13.3.4 Do the available microprocessors, software, and peripheral equipment interface with AISI to provide the required printouts and plots of surveying functions?

13.3.4.1 Criteria

a. AISI will require the availability of a microcomputer, printer, minimum 24-inch wide drum plotter (multi-pen), and modules of software data reduction and processing routines for Construction and Topographic survey products. These necessary support peripherals will be located at existing central reduction facilities for use by multiple AISI users. AISI software must be compatible with both the AISI and with the peripheral equipment. AISI peripherals and accessories should be introduced into the equipment inventory to support AISI in the same manner and at the same time AISI becomes part of the inventory, and be subject to the same evaluation and training requirements as AISI.

(1) External microprocessor capabilities.

- Fully MS/DOS compatible with AISI and other peripherals.

- Direct interface with the data storage device.

- Direct interface to a printer and plotter.

- Must be fully compatible with microprocessor.

- Software package shall consist of a full range of available, AISI compatible geodetic, topographic, and construction engineering programs.

(2) Plotter characteristics.

- Must be fully compatible with microprocessor.

- Must work with a minimum size format of 24 by 30 inches.

- Should have a multi-pen capability for different colors and pen sizes.

13.3.4.2 Data Required

a. Verification of external microprocessor capabilities, to include:

(1) Full MS/DOS compatibility with AISI and other peripherals.

(2) Direct interface with the data storage device.

(3) Direct interface to a printer and plotter.

(4) Full compatibility with microprocessor.

(5) Software package consisting of a full range of available, AISI-compatible geodetic, topographic, and construction engineering programs.

b. Verification of plotter capabilities:

(1) Full compatibility with microprocessor.

(2) Ability to work with minimum size format of 24 by 30 inches.

(3) Multi-pen capability for different colors and pen sizes.

c. Stored test data from field operational testing (described in paragraph 13.3.3.2.a above) will be used as input to the processing station for the required survey operations, computations, and processed output specified in Appendix VII, AISI Test Task Check Sheets, in the engineering services contractor's test plan (Reference 7).

13.3.4.3 Evaluation Methodology. Test results will be assessed to determine whether the AISI candidates demonstrate ability to meet the military requirements for topographic and for construction surveying operations as specified in the TSS ROC (Reference 1), O&O Plan (Reference 2), SEDME Specification (Reference 4), and Topographic Operation FM 5-105 (Reference 5). Results of the MAUT will be used to indicate the ability of the three candidates (designated by A, B, and C codes) to fulfill military requirements for surveying operations.

13.3.5 Does the AISI meet the established reliability requirements and, if not, what impact will this have on mission requirements?

13.3.5.1 Criteria

a. Quantitative reliability requirements will be established and included when the RAM Rationale Report (RRR) is completed. However, the AISI must have a high probability of completing the following mission requirements:

(1) The topographic surveyor furnishes field artillery weapons positioning and azimuth control on a continuing basis 12 hours per day, 7 days per week during wartime operation. Peacetime duties normally consist of solidifying and densifying control as needed for 10 hours per day, 5 days per week.

(2) Construction surveyors in wartime run route reconnaissance, surveying bridges, roads, airfields, culverts, etc., for 12 hour days, 7 day weeks. During peacetime operations, the only difference is that the time is shortened to 10 hour days and 5 day weeks.

13.3.5.2 Data Required

a. Total operating time for each test item.

b. A listing of incidents with the following information:

(1) Test item serial number.

(2) Operating time to incident.

(3) Cause of the incident.

(4) Description of any corrective actions taken.

(5) Total down time or total maintenance time.

(6) Description of the effect on system performance.

c. A description of operating modes and environmental conditions during the test.

d. Scoring conference results.

13.3.5.2 Evaluation Methodology

a. The thrust of the independent evaluation will be to determine the reliability characteristics of the AISI and to identify equipment malfunctions which reduce the military utility or degrade the mission capability of the system.

b. Test incidents will be charged based on the Failure Definition and Scoring Criteria for AISI.

c. The MTBF of the system will be calculated as a point estimate and at an 80 percent lower confidence level.

13.3.6 Does the logistics supportability plan for the AISI system (AISI with support equipment and software) satisfy mission needs and what is the impact on the overall logistics supportability if any of the elements listed below are not met?

a. End-Item Requirements.

b. Supply Support.

c. Technical Data/Publications.

d. Support and Test Equipment.

e. Manpower and Personnel, Training and Training Devices.

f. Transportation and Handling.

13.3.6.1 End Item Requirement

a. Criteria.

(1) The operation and maintenance (whatever level required) must be performed by military personnel without contractor support. The maintenance ratio will be no more than 0.05.

(2) The operators will be able to service the AISI in 15-30 minutes.

b. Data Required.

(1) Test Incident Reports (TIR's) completed as prescribed by DARCOM Reg 70-13.

(2) A complete history of all scheduled and unscheduled maintenance actions.

(3) Comments and findings on the system design for adherence to good maintainability principles.

(4) Results of Scoring Conferences.

c. Evaluation Methodology.

(1) The quantitative maintainability indices will be calculated at the appropriate levels.

(2) AMCP 706-132 will be used as a guide is assessing the maintainability of the system. A subjective analysis of test results, based on experience and professional judgement of military personnel will be performed to determine design adequacy.

13.3.6.2 Supply Support

a. Criteria.

(1) Repair parts will be authorized in adequate quantities and diversity at the appropriate maintenance levels.

(2) Repair parts will be consistent with the Maintenance Allocation Chart (MAC), Repair Parts and Special Tools List (RPSTL), and skills required to install and align parts.

b. Data Required.

(1) Repair parts consumption history during the testing.

(2) Comments on the ease of installation, alignment, and check-out of the repair parts.

(3) Comments on the compatibility of the systems repair parts with those listed in the RPSTL.

c. Evaluation Methodology.

(1) A projection of support requirements will be made to include estimates before and after any corrections.

(2) A narrative discussion of the adequacy of the support will be provided. Where an inadequacy is found, it will be documented with a complete description of the problem, its impact on operations, the cause of the problem, and recommendations to correct the problem.

13.3.6.3 Technical Data/Equipment Publications

a. Criteria.

(1) The technical data/equipment publications shall adequately reflect the system they support.

(2) The technical data/equipment publications shall be easily and completely understood by the maintenance personnel to whom they are addressed.

b. Data Required

(1) Findings as recorded for the Technical Data/Publications Chart, Appendix H, TECOM Supplement 1 to DARCOM-R 700-15 (Reference 10).

(2) Comments on technical manuals IAW Appendix E, TECOM Supplement 1 to DARCOM-R 700-15.

(3) Copies of any DA Forms 2028 prepared on any technical publications.

c. Evaluation Methodology. A projection will be made of the useability of the publications when fielded.

13.3.6.4 Support and Test Equipment

a. Criteria.

(1) The special/common tools, and support and test equipment shall be necessary and adequate for the performance of all authorized maintenance tasks at each level of maintenance.

(2) The design of the system should permit the use of common tools whenever possible.

b. Data Required.

(1) Findings as recorded in the format of the Support and Test Equipment Chart, Appendix I TECOM Supplement, DARCOM-R 700-15.

(2) Comments on the adequacy of the common and special tools and the support and test equipment. Comments on the same items where they are found to be needed but not provided by the System Support Package (SSP).

c. Evaluation Methodology. Each support and test equipment item will be subjectively analyzed for adequacy, necessity, and risk when fielded.

13.3.6.5 Manpower and Personnel, Training and Training Devices

a. Criteria.

(1) The skill levels shall be appropriate for maintenance.

(2) The number of personnel shall be adequate for maintenance.

(3) The training provided shall be sufficient to impart the necessary skills for maintenance.

b. Data Required

(1) Comments on the adequacy of the type and number of personnel selected for maintenance support.

(2) Comments on the suitability, effectiveness, and adequacy of the training of personnel and of the training devices (if any).

c. Evaluation Methodology

(1) A subjective analysis will be made of the overall quality of training provided.

(2) Each incident in test that was adversely affected by training will be subjectively analyzed for correction.

13.3.6.6 Transportation and Handling

a. Criteria. The AISI shall have the same transportability requirements as the current mobile survey equipment.

b. Data Required. The data collection requirements are given in paragraph E-1F, Appendix E, TECOM Supplement 1, DARCOM-R 700-15.

c. Evaluation Methodology. The measured and observed data will be summarized and analyzed for compliance with transportability requirements specified in AR 70-47.

13.3.7 Can the AISI meet MANPRINT requirements (elements of HFE, RAM, ILS, New Equipment Training (NET), and personnel safety/health hazard) when operated and maintained by MOS-qualified, NET-trained, experienced personnel wearing clothing and equipment appropriate for the operating and maintenance environmental conditions?

13.3.7.1 Criteria

a. LCD display readable in daylight or dark.

b. Illuminated reticle for night observations.

c. AISI, when used in the field data collection phase of operations, will be utilized by a crew of three topographic surveyors (MOS 82D) or construction surveyors (MOS 82B) similar to current operations. When the AISI is used in the data reduction phase, only one person should be required for each 12-hour shift, as opposed to the five required to provide quality control and supervision for the manual processing of field data in a 24-hour time period of operations. The AISI will have systems, health assessment, and human factors evaluations as required.

d. Maintenance for the AISI will be totally conducted by the contractor personnel throughout the life cycle.

e. All HFE data shall comply with MIL-STD-1472C (Reference 11) and any other applicable requirements documents. Manuals must be written in accordance with TOP 1-2-609 (IMAGES) (Reference 12).

f. The AISI shall comply with the human factors engineering program requirements of AR 602-1 and MIL-H-46855, and shall be designed in compliance with applicable environmental protection requirements of AR 200-2.

13.3.7.2 Data Required

a. A task analysis in sufficient detail to reveal areas of operator overload of stress, areas requiring task-specific training and areas particularly sensitive to operator errors.

b. Adequacy of illumination of scales.

c. Adequacy of labeling, wording, color coding, and keying.

d. Adequacy of protection from laser emissions.

e. Adequacy of human factors design for maintainability and operability.

f. Adequacy of the HFE design to include the 5th percentile female through the 95th percentile male soldier.

g. Adequacy of design of all work stations of the system.

h. Error and analysis of SOMTE operators and maintainers of the system.

i. Comments of SOMTE operators and maintainers of the system on HFE aspects of the system that might detract from the military utility of the system.

j. Observations, questionnaires, and performance tests as necessary to determine the effectiveness of New Equipment Training (NET) provided for the system.

k. Other questionnaires and rating scales as required.

13.3.7.3 Evaluation Methodology

a. All HFE data should be taken by a qualified human factors engineer; objective measurements can be made at any time during the testing. Subjective data, including that from interviews and questionnaires, should be taken three times during the testing: once soon after the start of the test program; once near the midpoint; and at the end of the test program. Such data will be used to indicate changes in attitude and to evaluate learning effects as well as to evaluate the AISI.

b. Test preparation and testing procedures will be carried out in accordance with TOP 1-2-610 and TECOM Pamphlet 602-1. Computers and Computer Displays will be evaluated in accordance with TOP 1-1-059.

c. All HFE data will be analyzed by a human factors engineer to determine compliance with the MIL-STD-1472C and any other applicable requirements document. Subjective data will be reviewed to detect any design or functional problems, and to ascertain their importance. All quantitative and qualitative data will be reduced to tabular or graphical forms and be summarized in terms of findings, conclusions, and recommended actions. The evaluation of the manuals will be performed in accordance with TOP 1-2-609 (IMAGES).

13.3.8 *Have the safety and health hazards associated with AISI operation, maintenance, transportation, and storage been controlled to an acceptable level?*

13.3.8.1 Criteria

a. The AISI shall comply with the system safety and health hazard program requirements of ARs 385-10, 385-16, 40-5, 40-10, and MIL-STD-882B (Reference 13).

b. The AISI shall not present uncontrolled, catastrophic, or critical residual safety or health hazards. Safety deficiencies, defined as Category IA, IB, IC, ID, IIA, IIB, IIC, and IIIA risks, shall be eliminated or controlled by design whenever feasible.

c. The AISI design must comply with the intent of MIL-STD-454, requirement 1 (safety), for operator and maintainer safety.

d. Ionizing radiation sources shall not be used without prior notification and approval. When use is necessary, the source(s) shall be controlled IAW regulatory and statutory requirements.

e. Non-ionizing radiation sources (e.g., laser or other directed energy device) used in design must be approved, and should not present a hazard to personnel during operation (e.g., eye-safe laser).

13.3.8.2 Data Required

a. Total operating time for each test item.

b. A listing of incidents with the following information:

(1) Test item serial number.

(2) Operating time to incident.

(3) Cause of the incident.

(4) Description of any corrective actions taken.

(5) Total down time or total maintenance time.

(6) Description of the effect on system performance.

c. A description of operating modes and environmental conditions during the test.

d. Scoring conference results.

13.3.8.3 Evaluation Methodology

a. The thrust of the independent evaluation will be to determine the reliability characteristics of the AISI and to identify equipment malfunctions which reduce the military utility or degrade the mission capability of the system.

b. Test incidents will be charged based on the Failure Definition and Scoring Criteria for AISI.

c. The MTBF of the system will be calculated as a point estimate and at an 80 percent lower confidence level.

13.3.9 Does the AISI meet the MIL-STD-461B requirements for electromagnetic interference/electromagnetic compatibility?

13.3.9.1 Criterion

The electromagnetic interference emission and susceptibility characteristics shall conform to MIL-STD-461B, methods RE02 for radiated and CE03 for conducted tests, for Class B equipment. The frequency spectrum shall be from 0.014 through 1 GHz during the radiated tests and from 0.020 through 50 MHz during the conducted tests with the following exceptions: (a) broadband radiated emissions (RE02) at 0.3 MHz and 0.7 MHz shall be increased by 5 dB and, (b) broadband radiated emissions (RE02) at 150 MHz shall be increased 6 dB above the requirements of MIL-STD-461B, as specified for similar type equipment such as SEDME.

13.3.9.2 Data Required

a. EMI/EMC test data specified in the PD, MIL-STD-461B, and MIL-STD-462.

b. Compatibility and interoperability test results that relate to the ability of the AISI to operate with the communication and electronic equipment. This data will be obtained from user field operational testing of the AISI system and from analysis of the operating characteristics of the equipment involved.

13.3.9.3 Evaluation Methodology. The EMI and EMC of the AISI will be tested and evaluated in accordance with the provisions of the PD, MIL-STD-461B (Reference 8), and MIL-STD-462 (Reference 9). Test results will show whether the conducted and radiated EMI emissions are within acceptable limits. An analysis will be conducted to determine whether the AISI meets electromagnetic compatibility requirements and to estimate the effects of excessive EMI on communication and electronics equipment that operate within the vicinity.

13.3.10 Does AISI meet the physical design characteristics such as weight, size, and rigidity?

13.3.10.1 Criteria

a. Commercially available shapes are acceptable. Maximum weight of the total system has not been determined at this point in time. However, the maximum weight of each package shall not exceed the maximum safe lifting requirements for personnel as required by MIL-STD-1472C.

b. AISI design should include the following characteristics:

(1) Built-in corrections for curvature, refraction, and slope.

(2) An electronic compensator for mislevel of the instrument.

(3) Ability to compensate for eccentricity of the instrument.

(4) Impact-resistant carrying case and instrument test and repair kit.

(5) Optical plumbing device.

(6) Capable of tilting to at least 100 percent slope (45 degrees) up and down.

13.3.10.2 Data Required

a. Physical dimensions and weight.

b. Verification of item manufacturer specifications.

c. Photographs of the equipment and of any problem areas with system design.

d. Tabulated comments concerning physical design problem areas.

13.3.10.3 Evaluation Methodology. The evaluation will be based on the assessment of the results of the initial inspection and specific tests conducted by the engineering services contractor to determine the physical characteristics of the AISI candidates. The degree to which the AISI candidates comply to the manufacturer's specifications will be assessed. The evaluation will consist of a determination whether the the military requirements for AISI physical characteristics are satisfied. The evaluation results will also indicate whether AISI has the potential to accomplish the mission profile/operational mode summary established for the proposed AISI system.

13.3.11 Is the electric power source acceptable for reliable AISI operation in compliance with the operational mode summary/mission profile?

13.3.11.1 Criteria

a. AISI must have a power source of both internal, rechargeable battery and external 12- to 24-volt dc vehicular battery.

b. The external microprocessor should have a power supply of 110-220 volts ac with battery backup to prevent loss of data if primary power is interrupted.

13.3.11.2 Data Required

a. Verification of capabilities of the power source of both internal, rechargeable battery and external 12- to 24-volt dc vehicular battery.

b. Verification that the external microprocessor has a power supply of 110-220 volts ac with battery backup to prevent loss of data if primary power is interrupted.

13.3.11.3 Evaluation Methodology. The methods of AISI power for field operation, to include internal, rechargeable battery and 12- to 24- volt dc vehicular battery will be evaluated using test data from the Market Investigation. The AISI will be evaluated for ability to meet the requirements for mission completion using battery power IAW the mission profiles established for topographical and construction surveying operations.

13.3.12 Is the AISI compatible with the Army Standard equipment that it is required to interface with?

13.3.12.1 Criteria

a. The AISI shall be compatible with the standard U.S. Army tripods and tribachs.

b. The AISI will use the Doppler Satellite Survey System and Global Positioning System for extension of prime control established with these systems. It will be used for alignment and updating position data of the Position and Azimuth Determining System and other Inertial Navigation Systems. The microprocessor will allow direct access to data base allowing for rapid dissemination of the information contained in them.

13.3.12.2 Data Required. Problems concerning inability to be mounted on the standard military tripod.

13.3.12.3 Evaluation Methodology. Problems reported will be assessed for their impact on system operation.

14. ANTICIPATED SOURCES OF DATA

BRDEC appointed an engineering services contractor to develop a test plan and conduct testing during the Market Investigation. No other testing is planned prior to the Milestone I/III decision scheduled for 2Q FY88. Technical performance, environmental performance, operational performance, HFE, reliability, and safety subtests of the engineering services contractor's test plan were reviewed and were assessed as adequate for acquiring data needed for evaluation use. Additional test and planning data required for the evaluation include environmental (fungus), logistic supportability, high-altitude EMP, and chemical decontamination. Additional data will be obtained from interviews with the BRDEC materiel proponent and with military surveying operations personnel at the Engineer School who will be the potential users of the AISI. A technical IER will be prepared for the Milestone I/III IPR. If the results of the IPR review are favorable for production and fielding AISI, then the generic purchase description that is to be type classified must be coordinated with TECOM. A technical Independent Evaluation Plan will be prepared by TECOM for the First Article Test.

REFERENCES

1. Topographic Support System ROC, TRADOC, 1978.

2. Operational & Organizational Plan for the Automated Integrated Survey Instrument, TRADOC, 15 October 1986.

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

4. Military Specifications, Surveying Equipment, Electronic Distance Measuring, Medium-Range, MIL-S-53046, 15 August 1984.

5. Field Manual for Topographic Operations, FM 5-105, TRADOC, date unknown.

6. Draft Test and Evaluation Master Plan for AISI, BRDEC, unpublished as of July 1987.

7. Operational/Environmental/Suitability Test Plan for the AISI, prepared for U.S Army Belvoir Research, Development, and Engineering Center, April 1987.

8. MIL-STD-461B, Electromagnetic Emissions and Susceptibility Requirements for the Control of Electromagnetic Interference, 1 April 1980.

9. MIL-STD-462, Electromagnetic Interference Characteristics, Measurements of, 31 July 1967 with notices 3 and 4, 9 February 1971.

10. DARCOM Regulation 700-15, Integrated Logistics Support, 26 November 1979, w/Chg 1, 26 December 1979.

11. MIL-STD-1472C, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, 2 May 1981.

12. MIL-STD-882B, System Safety Program Requirements, 30 March 1984.

APPENDIX A

CHECKLIST FOR THE AISI EVALUATION

A checklist of characteristics or attributes will be used by the independent evaluator as a tool to analyze surveying operations characteristics of the AISI candidates (to be designated by A, B, and C codes to preclude contractor identity). Each attribute will be assessed and the results will be obtained at the time of evaluation. The results will be based on all available test data from the Market Investigation, verified technical specification data from the item contractor, and information from the Government materiel and combat developers.

The attributes that will be used in the analysis are presented in the following checklist taken from Appendix VII of the contractor tester's test plan (Reference 7).

File Handling

The ability to create and manipulate files for coordinate storage. Optionally, files may contain unreduced raw field data, descriptive information, plot sequences and a record of keystrokes. The more file handling routines contained within the program, the better. Typically, some basic file handling routines are handled within the program, while the more advanced functions must be performed by exiting to the operating system.

Tasks/functions to look for include.

- Create a File - User may name a file (project, job, etc.) and create storage space where all coordinates for that project will be stored. There may be restrictions on the minimum and maximum number of points per file.
- Change a File - Renames or changes descriptive header information (e.g., client name, job name, et.) about a file.
- Extend a File - Expands the number of points in a file. Useful when the number of points, goes beyond the original number set up. Sometimes this is done automatically.
- Merge Two Files - Combines two different jobs into one file.
- Purge a File - Erases a file.
- Copy a File - Backs up, or copies, individual data files.
- Catalog of Files - Lists the names of all files on a disc. Optionally, may include more descriptive information about each file.
- Copy Entire Disc - Backs up, or copies, all data files on a disc.
- Coordinate Transfer (Any block of points) - Transfers a user specified range of coordinates from one file to another. Useful for working in separate jobs, with common boundaries.
- Format Disc - The process by which the user erases all exisiting data and formats a disk to accept data in accordance with operating system or program requirements. Usually done with a new disc, prior to initial use.

	Wild Heerbrugg	Geodimeter	Cubic
File Handling			
Create a File			
Change a File			
Extend a File			
Merge Two Files			
Purge a File			
Copy a File			
Catalog of Files			
Copy Entire Disc			
Coordinate Transfer			
Format Disc			

Overall Data Entry & Computation

Refers to the entry and computation of values, such as coordinates, distances, directions, areas, etc. Accuracy, precision and flexibility of data entry are important considerations.

Tasks/Functions to look for include:

- Computed Precision - The precision to which coordinates, distances, directions, and areas are computed by the program. Usually depends upon the significant digits possible within the computer or the software program.

- Stored Precision - The precision to which coordinates, distances, and directions are stored by the program.

- Maximum Significant Digits - The maximum number of digits possible for coordinates, distances, directions, and areas. For example, there is no sense using the actual state plane coordinates for your computations, if your computations are handled by a floating point system, with an 8 place mantissa, since a coordinate value of 1,234,567.892 might be used as 1,234,567.9.

- Digits To the Right of Decimal - User may specify number of digits output to the right of the decimal for coordinates, distances, directions, and areas. Values should be computed to the highest possible precision, but may be printed as specified by the user.

- Directions & Distance Conventions/Units - The ability of the program to accept, compute, output and store different conventions/units for directions and distances. Directions may be bearings, north azimuth, south azimuth, deflection left/right, angle left/right, etc. Distances may be in feet, meters, chains, etc. Some programs accept unreduced field notes that contain rod readings, stadia readings, etc. These are then automatically reduced to coordinates by the program.

- Point Protection - Protects existing points from being overwritten by the program. Operator is usually given the option to overwrite the point or choose a new point number.

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Field Traverse

The entry, reduction and adjustment of observed field data, such as slope distance, vertical angle, horizontal angle, target height, instrument height, EDM offset, rod readings, etc. The entry and use of constants (curvature of the earth, refraction of light, temperature, chain tension, scale, etc.) for use in reduction computations should be an integral part of these routines. Some of these reductions may be made by the field instrument or data collector, but it is a good idea to have them, in case they are needed. Standard adjustments should also be included.

Tasks/functions to look for include:

- <u>Sideshots</u> - Are sideshots entered during raw traverse data entry or after adjustments? Some programs give you the option of both. If input with raw traverse data, they may be recomputed, based upon adjusted coordinates, or left unadjusted, so be careful.

- <u>Manual or Auto. Pt. Numbering</u> - The ability of the program to automatically number points in sequence. Some programs number sequentially, but not automatically (a "+" is entered instead of the next point number). May provide the capability to switch back and forth between auto and manual numbering.

- <u>Types of Traverse</u> - Refers to the types of traverse the program will handle. Maximum number of courses, type of directions allowed (angle right/left, deflection right/left, bearings/azimuths) and whether elevations may be carried with the traverse are important considerations. The ability to enter point descriptors is also important. Some programs provide the ability to use the last entered angle code as a default. If your traverses are all angle right, this saves one step per leg. In addition, it is sometimes possible to temporarily store a long traverse and restart raw data entry at a later time. Types of traverses to look for include:

  - <u>Closed (Internal Reference)</u> - The beginning and ending points are the same and the reference direction is one of the traverse legs.

  - <u>Closed (External Reference)</u> - The beginning and ending points are the same and the reference direction is external to the traverse.

  - <u>Point to Point</u> - The beginning and ending points are different, but have fixed coordinates.

  - <u>Open</u> - The beginning and ending points are different and only the beginning point has fixed coordinates. No adjustments are possible.

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	Wild Heerbrugg	Geodimeter	Cubic
• Saves Raw Data Separately - Program saves unadjusted raw data (directions and distances) in a separate raw data file. Some programs require the creation and transfer of data to a separate file, while others automatically create a separate "Field file" as a subset of the main coordinate file. Very important, especially if you want to run multiple closures on the same data, or you need to come back at a later time to correct some undetected error.			
• Multiple Adjustments - The ability of the program to perform different types of common adjustments. May be possible to perform all adjustments and compare coordinates. Closing distance, difference in closing and starting coordinates, angular misclosure, ratio of precision, distance traversed and area may be computed and printed. Errors and precision should be computed before angle balancing and adjustment. Some programs are able to automatically find this error of closure by holding each leg in turn and printing a report of the trial closures. Adjustment types may include:			
- Least Squares - Simultaneously adjusts the angular and linear measurements to make the sum of the squares of the residuals a minimum.			
- Compass Rule - The correction to be applied to the latitude of any course is to the total error in latitude as the length of the course is to the length of the traverse. The corrections to the departures follow the same rule.			
- Crandall Rule - The angular misclosure is first distributed in equal portions to all the measured angles. The adjusted angles are then held fixed and all remaining corrections placed in the linear measurements through a weighted least squares procedure.			
- Transit Rule - The correction to be applied to the latitude of any course is to the total error in latitude as the latitude of that course is to the arithmetical sum of all the latitudes in the traverse. The corrections to the departures follow the same rule.			
- No Adjustment - No adjustment is performed. Raw data is used to calculate coordinates.			
- Angle Balance - Spreads the total angular error among the turned angles. Usually spreads the error equally, but may include the option to spread the error as the user sees fit or hold specific angles. Sometimes done before adjustment.			

- Insert Leg - Inserts a missing leg in a traverse. Balancing and adjustment is then performed on the corrected data.

- Delete Leg - Deletes an extraneous or incorrect leg from a traverse. Balancing and adjustment is then performed on the corrected data.

- Correct Leg - Corrects a direction and/or distance of any traverse leg. May be performed before, or after, closure is determined. Balancing and adjustment is then performed on the corrected data.

- Hold Leg - Holds a known true leg. Balancing and adjustments are not performed on the held leg.

Coordinate Geometry

The use of coordinate geometry equations to calculate coordinates of points, areas, intersections of lines and curves. The computation of line and curve parameters such as bearing, distance, central angle, etc. are also included.

Two outstanding features, multiple point computation and lines, are not part of any one task/function and deserve special mention.

Mulitple point computation refers to the ability of the program to automatically perform similar computations on groups, or ranges, of points, rather than on a point to point basis. This saves keystrokes and increases productivity. Routines that take advantage of this benefit include; auto traverse and inverse, divide a line, street intersection, cul-de-sacs, point/traverse intersection, etc.

A lines routine, on the other hand, may combine such functions as traverse, inverse, bearing/bearing, etc. into one routine. The user merely enters the known information and the computer automatically performs the correct computation.

Tasks/functions to look for include.

- Area Computations - Computes areas using known points.

- Cogo Traverse (No Adjustments) - Computes forward coordinates given occupied station, backsight station, angle and distance. Forward station then becomes occupied station. No adjustments are performed.

- Sideshots - Computes sideshot coordinates given occuppied station, backsight station, angle and distance. Occupied station remains the same.

- Auto Traverse Along a Line - Computes a series of forward points along the same bearing at a common distance.

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- Divide into Equal Segments - Divides the distance between two known points into equal segments, given the number of segments. May apply to a straight line, curve, spiral, or figure.

- Inverse - Computes direction and distance information between two known points. In the case of a curve, computes curve data (arc length, central angle, etc.), given the P.C., P.T. and radius point. May also compute area at the end of inverse computations.

- Auto Inverse - Inverses between a series of known points.

- Curve Computations - Computes a point on curve, given the P.C., radius point and one of the other curve parameters. May also include computation of unknown curve parameters from known parameters, without computing coordinates.

- Inscribe Curve Between Two Lines - Inscribes a curve between two lines, given the P.I., the bearings into and out of the P.I. and one other curve parameter.

- Line Intersections - Computes coordinates of the intersection of two lines between two known points, given some combination of distance and bearing information. May include bearing/bearing, bearing/distance, distance/distance and bearing/bearing with offset. Sometimes has two distance/distance solutions, both a near and a far.

- Coordinate Manipulation - Creates, stores, recalls, lists, or clears coordinates. May include the ability to add, or delete, descriptors/elevations at a later time. Applies to groups (sets, figures, etc.), as well as individual points. Some programs automatically store points to a file in order to prevent data loss.

- Edit and Reprocess Coordinate Computations - Recomputes all desired coordinate computations after a change or correction is made. Often called batch processing or keystroke recording. Eliminates the need to recompute all related computations. Unusual in a COGO package.

- Lot Summary - Computes the distance, bearing, curve information and area of a lot, given the lot corners. May also be accomplished using inverse. May include the printing of closing information and rounding of distances and bearings. Some programs generate reports, comparing individual areas to total area and individual lot frontages to total block frontages. If the values are within a specified tolerance, then rounding is done so that the sum exactly equals the parts. Useful for plat drafting and checking.

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- Street Intersections - Computes the radius point, P.C. and P.T. of all four corners of a street intersection, given the centerline bearings, the corner radii and the widths of the intersecting streets. Usually includes straight/straight, curved/curved, or straight/curved street intersections. Sometimes includes an option to suppress computation of one or more of the corners.

- Offset Intersections - Computes a point at a specified offset(s) from two intersecting lines, given the bearings into, or out of, the intersection point.

- Point/Traverse Intersection - Computes the intersection of lines to a traverse, given known points and the direction of the lines between the points and the known traverse. The known traverse may be composed of straight line and/or curves. Sort of a multiple bearing/bearing intersection. Useful for computing the front lot corners, when the back lot corners and directions of the side lot lines are known.

- Proportion Between Points - Proportions distances along a traverse made up of straight lines and/or curves. The last computed point is compared to the known end point and the closure error is proportioned among the individual distances. May include the ability to "hold" certain distances.

- Point to Point Area - Similar to inverse with area, or lot summary. May include a curve, or spiral leg.

- Rotate/Translate - Rotates a group of points, given an angular rotation and/or a new starting location.

- Comment - Inserts user comments on the printout. Useful for instructions to field crews.

- Cul De Sacs - Computes the radius point, P.C. and P.T. of all cul-de-sac curb returns, given the center point, main radius, curb radius and the width and bearing of the intersecting street. Often includes bulb, offset and knuckle cul de sacs.

- Standard Templates - Creates, stores and recalls standard templates (figures, details, etc.) for placement at specified locations. Almost always includes the ability to rotate/translate and may include the ability to rescale and mirror the template. Useful for positioning standard building footprints.

- Figure/Line, Curve, Spiral Inter. - Computes intersection points of a figure with a line, curve, or spiral, given a known point and direction.

	Wild Heerbrugg	Geodimeter	Cubic
Street Intersections			
Offset Intersections			
Point/Traverse Intersection			
Proportion Between Points			
Point to Point Area			
Rotate/Translate			
Comment			
Cul De Sacs			
Standard Templates			
Figure/Line, Curve, Spiral Inter.			

Function	Wild Heerbrugg	Geodimeter	Cubic
• Predetermined Area - Computes the end point(s) of a line that will yield a user specified area of a lot. Usually includes parallel sides (rectangular lot) and hinged side (triangular lot), but may also include radial sides (cul-de-sac lot).			
• Radial Stakeout - Computes the angles and distances to be turned to known staking locations, given the occupied and backsight station. Sometimes computes bearings and/or azimuths in addition to turned angles. May provide the capability to limit computations to those points within a user specified distance of the occupied point.			
• Offsets from a Base Line - Computes the offset left/right and station of known points in relationship to a known baseline.			
• Renumber - Renumbers a range of points, given the old point number range and the new starting point number.			
• Proportionate Measurement - Computes the location of a point given 2 or four distances from 2 or 4 known points to the unknown point. Useful for locating lost corners.			
• Circle thru Three Points - Computes the radius distance and radius point coordinates, given three points on a horizontal curve.			
• Line Tangent to Circle - Computes the point of tangency for a point outside of a circle, given the radius point coordinates, the radius of the circle and the coordinates of the point outside the circle.			
• Right of Way (Parallel Traverse) - Computes a left and/or right offset line paraleil to a given baseline, or centerline. May compute more than one offset (curb, sidewalk, property) line in the same operation. May also include curves, as well as straight lines.			
• Point to Point Angles - Computes clockwise and counter clockwise angles between three known points.			
• Search - Provides for the capability to perform a point search by coordinates, point number, descriptor. Useful for finding points with common characteristics.			
• Bearing Recall - Computes and recalls a bearing between two known points and uses it in coordinate computations. Useful for laying out parallel lines.			
• Distance Recall - Computes and recalls a distance between two known points and uses it in coordinate computations. Useful for dividing distances between lots.			

Wild Heerbrugg	Geodimeter	Cubic

- Integrated Math Computations - Integrates some math functions with the computation of coordinates. Usually used in conjunction with bearing and distance recall. For instance a user may be able to recall the bearing between points 1 & 3, add 90 degrees, then traverse a distance the same as from points 4 to 5, divided by 4. These should be integrated with coordinate computations and not a separate routine.

- Spiral Coordinates - Computes coordinates along a spiral curve, given some information about the spiral and some known coordinates.

- Spiral Parameters - Computes the remaining parameters of a spiral curve, given certain base information.

Plotting

Refers to plotting lines between points on a screen, printer, or plotter. Plotting elevations, contours, annotation and other descriptive information is a plus. In COGO packages, generally used as a visual check of computations and not used to produce finished drawings.

Tasks/functions to look for include:

- CRT, Printer or Plotter - Plots lines and/or points on a screen, graphics printer, or pen plotter. Usually requires user to scale, orient and develop a plot sequence before plotting is done. Usually plots point numbers and may provide some limited point and line annotation capabilities.

- Auto Plot/Scale to Screen - Computer automatically scales and orients the plot to the plotting surface. Useful for quick and dirty pictorials of previously entered data.

- Screen Plot as you Compute - Points and/or lines are plotted to the screen as they are computed. Some scaling and orientation is necessary.

- Zoom In/Out on Sections of Plot - Performs a screen blow up or reduction of sections of the plot by outlining desired section with a cursor.

- Window Sections of Plot - Similar to zoom in/out but requires user to specify the plot window by defining coordinate limits. Useful for obtaining hard copy output of sections of a plot.

- Load and Store Plot List - May store a plot sequence for later recall and replotting, or editing.

- Plot Contours - Interpolates and draws user specified contour lines between elevations. Usually not very automated and quite tedious.

- Plot Elevations - Plots elevations, in addition to point numbers and X Y coordinates.

Wild Heerbrugg	Coordinator	Cubic

Miscellaneous Prog. (Surveying)

Includes horizontal and vertical design computations, not generally found in COGO packages. Computations may or may not be stored. Sometimes used to generate design reports for stakeout, vertical curves, etc.

Tasks/functions to look for include.

- Radial Survey - The reduction of topographic raw survey data to coordinates. Sometimes integrated with traverse routine. May include reduction for a variety of field instruments and methods, including total station, top mounted EDM, two instrument and stadia surveys.
- Vertical Curves and Grades - Computes elevations and stations for parabolic vertical curves and straight line grades, given certain known characteristics, such as entry and exit grades, station interval, length of curve, etc. May include the computation of the high and low points, curve passing through a fixed point and non symmetrical curves.
- Baseline Stakeout - Computes stakeout deflections and distances for straight lines, circular curves and spiral curves.
- Section Division - Computes unknown section corners from known quarter, center, or other known points. May subdivide into 4, 16, 64 parts.
- Map Check w/Plot - Automatically draws unscaled sketch from map or property description bearings and distances. Usually computes area and closure error. Useful for checking record maps and property descriptions.
- Stadia Reductions - Reduces stadia notes to horizontal distance, vertical distance and elevation. When not integrated with coordinate computations, not much better than stadia tables.
- Coordinate Transformation - Converts between geographic position and state plane coordinates for various U.S. zones. Usually utilizes stored constants. May include Lambert, Transverse, Alaska Zones, Universal Transverse Mercator and Oblique Mercator projections.
- Resection - Computes occupied station from three, or more, known coordinates. Useful for stakeout.
- Coordinate Transfer From Other Programs - Provides coordinate compatibility and transfer from and/or to other programs. The most common examples are transfer with Hewlett Packard/Wild Volume C coordinate geometry, or AutoCAD's drafting program.

- Legal Descriptions - Facilitates writing legal descriptions. May be as simple as a basic text editor, or as sophisticated as automatically recalling common legal description terms, such as "to the point of beginning", "thence along a line", etc. May also be integrated with coordinate computations, so that points may be entered and automatically converted to bearings and distances by the program.

- Line Layout From Random Traverse - Computes coordinates of points on a baseline, or property line, from known points on a random traverse, offset from the baseline. May also compute distance and angle from the random traverse points to the baseline and distance from the start of the baseline. Useful when field obstructions make it impossible to run the traverse along the intended line.

- EDM Slope Reduction - Reduces raw slope distances to horizontal distances, based upon zenith angle, EDM offset, height of instrument, target height, curvature and refraction constants, etc. When not incorporated with traverse or coordinate computations, is little more than an expensive calculator. Taping reduction may also be included.

- Celestial Observation - Computes the azimuth of a line from observation of the sun, or a star. Ephemeris data is often incorporated in the program and stored on disc.

- Field Angle Check - Reduces and computes the mean of multiple sets of angles from either a repeating or direction instrument. May also compute deviation from the mean of individual angles and the spread between angles. When not incorporated with traverse computations, is little more than an expensive calculator.

- Automatic Data Collection - Accepts and automatically reduces data from field data collectors. Providing reduction programs for specific brands of data collectors is much better than generic data collection packages, because they take advantage of the specific capabilities of each. May also provide two way communication out to the data collector for automatic staking purposes. See modules on data collection and automated stakeout for more information.

- Vertical Plotting - Provides limited plotting of cross sections or profiles from elevation information. Not intended as a full capability road design or earthwork program.

- Triangle Solutions - Uses geometry to compute the missing sides and angle of a triangle.

	Wild Heerbrugg	Geodimeter	Cubic
Legal Descriptions			
Line Layout From Random Traverse			
EDM Slope Reduction			
Celestial Observation			
Field Angle Check			
Automatic Data Collection			
Vertical Plotting			
Triangle Solutions			

	Wild Heerbrugg	Geodimeter	Cubic
Field Instrument The ability of your electronic field instrument to track the target, compute and display distance/direction to stakeout point, communicate with the data collector, and calculate coordinates. Tasks/Functions to look for include.			
• On Board Computation - Usually, distances and directions are entered from the keyboard or uploaded from a data collector. Tracking and computation of relative stakeout values (direction, distance, etc.) is then performed. However, some instruments may be able to compute stakeout distance and direction from coordinates entered via the keyboard.			
• Number of Displays - Instrument displays all relevant stakeout data (angle to turn, azimuth, distance to point, coordinates of point, difference in coordinates to point, etc) simultaneously. The more displays, the better.			
• Tracking - Instrument tracks the reflector with instantaneous updates of distance. This is usually a coarse distance and is computed and displayed much faster than a distance taken during a control traverse. Some instruments track relative elevations and angles, as well. Measurement speed is important.			
• Countdown To Zero - Some instruments have countdown to zero capabilities that display a zero angle when the instrument is on line and a zero distance when the rodman is at the stakeout point. In other words, the angle to the line and distance to the stakeout point are tracked.			
• Beam Width - A wider measurement beam will allow the rodman to "wander" off line more, before the instrument loses the return signal. Usually specified as the angle between beam edges. The greater the angle, the better.			
• Time Out - Some instruments have time out of the beam restrictions. In other words, if the rodman is out of the beam for more than a specified period of time, the instrument will lose tracking and a new measurement will have to be initiated.			
• Display Difference - Computes and displays the angle and distance difference between the current point and the next point to be staked. An X and Y distance to the stakeout point may also be computed and displayed. Gives rodman clearer idea of where he should go next.			

Data Collector

Refers to the ability of the data collector to compute stakeout values from stored coordinates, upload them to the instrument and record as staked locations.

Tasks/Functions to look for include.

- Store/Recall Coordinates - Loads coordinates of known points into data collector memory for puposes of computation. May be transmitted to instrument for further computation. Also stores computed coordinates, such as "as staked locations".

- Coordinate Computation - As discussed previously, data collectors can perform many types of computations. Those related to stakeout include computation of stakeout directions and distances from known points, tracking computations (relative distances, directions and coordinates) and resection. Some even have programs designed to compute offset points from baselines. Useful in setting batter boards for building corners.

- Resection - Computes the occupied station by using triangular geometry and two or more known points. The greater the number of known points and the more distance/angle combinations possible, the better. May compute and record the accuracy (standard deviation) of the overall measurement and indicate the standard deviation of each resection point. Often called free station. Caution! The accuracy of your computation depends quite heavily on the geometry of your set up and the accuracy of each measurement so be aware of the math, before relying too heavily on the result.

- Two Way Communication with Instrument - Uploads information to the instrument and monitors intrument measurements during stakeout.

- Record "As Staked Locations" - Records the location actually staked in the field. May be recorded as absolute coordinates, relative coordinates (delta Z = cut or fill), distance left/right and in/out, direction and distance from occupied station, etc.

Wild Heerbrugg	Geodimeter	Cubic

Wild Heerbrugg	Geodimeter	Cubic

Auxiliary Equipment

Refers to electronic equipment that help rod and instrument man communicate.

- Radios - If you've ever tried to yell instructions to a rod man against a strong north wind, then you know two way radios can be important. Hand signals are a substitute, but not as productive.
- Receivers/Transmitters - Refers to one way communication. Rodman may have an electronic display which receives stakeout values from the instrument, or a radio type voice receiver. Transmitter is at the instrument.
- Tracking Lights - Device that emits a light from the instrument to the rodman. Usually changes color, depending upon whether you are left, right, or on line. Sometimes blinks at different frequencies as you get closer to exact line.
- Miscellaneous Equipment - Refers to staking aids, such as special targets, staking tripods, etc.

	Wild Heerbrugg	Geodimeter	Cubic
General Functions Refers to general capabilities and functions of the data collector. These may include:			
• <u>Measurement Sequences</u> - Number of different sequences with which a user may collect data. User may <u>select</u> from built in sequences, or <u>define</u> his own. A sequence refers to the order in which measured and observed data (slope distance, horizontal angle, vertical angle, target height, etc.) is collected.			
• <u>User Programmable Prompts</u> - User may define his own prompts. Generally allows built - in prompts to be modified to user terminology, or the addition of prompts not built - in.			
• <u>One Button Transfer</u> - Refers to the transfer of all measured data (slope distance, horizontal angle, vertical angle) to the data collector at the touch of one button. If that button is on the instrument, the data collector can be hung on the tripod, leaving the operator's hands free.			
• <u>Manual Data Entry</u> - Allows measured data to be entered manually from the keyboard. Desirable if field instrument is not electronically linked to the collector.			
• <u>Editing</u> - Corrects and changes collected data. Some retain both the original and corrected data. This may be required from a legal standpoint.			
• <u>Search</u> - Finds data by searching for a particular known point number, angle, distance, code, etc.			
• <u>Erase Edited Data</u> - Same as editing, only original data is destroyed. This may not be desirable. Some data collectors give you the option to erase or keep original data.			
• <u>Set Instrument Parameters</u> - Characteristics of different field equipment (EDM offset, prism offset, type of EDM, type of theodolite, etc.) may be input. These parameters are then reflected in all data reduction computations. Some of these may be set in the instrument.			
• <u>Set Measurement Parameters</u> - Sets the characteristics of measured data (curvature & refraction, sea level correction, pressure/temp, etc.). These parameters are then reflected in all data reduction computations. Some of these may be set in the instrument.			
• <u>Set Angle & Dist. Toler.</u> - Sets angle and distance tolerances for multiple measurements. The user is then warned when the measurement does not meet tolerances.			
• <u>Direct or Repeat. Angles</u> - Records angles with either a direction or repeating instrument.			

- Multiple Angle Sets - Records multiple turned angles for later reduction by either the data collector, or an office software package.

- Automated Plot Codes - Numeric codes, which will later be decoded by the office software to plot a symbol, or a line between points may be entered.

- Time Stamps Data - Provides some method of automatically recording the time and date of measurements.

- Records Multiple Jobs - Records data for more than one project at a time. Should be recorded in separate, designated files.

Data Recorded

The ability of the data collector to record measured and observed data. The following may be recorded.

- Project Reference - Descriptive information for each project. May include file name, project name, client name, field crew, etc.

- Instrument Parameters - See Set Instrument Parameters above.

- Measurement Parameters - See Set Measurement Parameters above.

- Descriptive Notes - Text may be entered to further describe points, conditions, etc.

- Point Code - An alpha or numeric code designed to describe the point being measured. Usually, decoded by the software and translated into a descriptive note, and/or plotted symbol.

- Point No. - Point number recorded with measured data.

- Occupied Station - The instrument station from which measured data is taken.

- Ht. Instrument - The vertical distance from the instrument center ground point to the horizontal axis of the telescope.

- Ht. Target - The vertical distance from the measured ground point to the center of the reflector/prism.

- Slope Distance - The measured slope distance from the center of the instrument to the reflector.

- Horizontal Angle - The measured horizontal angle between the backsight and target.

- Vertical Angle - The measured vertical angle between the target and either the vertical axis (zenith angle), or the horizontal axis (vertical angle) of the instrument. Sometimes referred to as zenith angle.

[illegible]	Coordinates	[illegible]

Duplication of Data

The ability of the data collector to duplicate repetitive data automatically. Very important in determining overall ease of use and field productivity. The following may be duplicated.

* Point Code - Automatically repeats the last point code, unless told differently by the operator.

* Point No. ± 1 - Automatically increments the point number by one, until told differently. Sometimes decrements number by one.

* Ht. Target - Automatically repeats the last target height, until told differently.

Built-In Programs

The ability of the data collector to act as a calculator, or computer. Refers to built in "turn-key" programs provided by the manufacturer. Some of these calculations may be performed by the field instrument and the results transmitted to the data collector.

* Traverse - Records backsight, occupied and foresight station data in such a way that the data collector and/or an office computer may compute traverse coordinates. Optionally, may compute and record coordinates and compute closure error.

* Topography - Records backsight point, occupied station and sideshot target data in such a way that the data collector and/or an office computer may compute coordinates. Optionally, may compute and record coordinates. Some record both measured data and reduced coordinates. Useful for topographic surveys.

* Stake Out - Allows the operator to stake out points from coordinates stored in the data collector. Data collector calculates angle and distance, based upon known coordinates of the backsight point, occupied station and stakeout point. May provide two way communication of distance and angle to stakeout point, record "as staked coordinates", compute cut/fill, etc. Sometimes referred to as "setting out". Discussed in more detail in Module 4.

* Inverse - Computes distance and direction information between two points of known coordinates.

* Resection - Computes the occupied station by using triangular geometry and two or more known points. The greater the number of known points and the more distance/angle combinations possible, the better. May compute and record the accuracy of the measurement. Useful for stakeout applications (see Module 5 for a more complete definition).

* Remote Elevation - Computes the elevation of an inaccessible target point above/below a measured ground point.

* Calculate Coordinates - Computes the coordinates of a point by its relative position to a known point. Uses measured data.

Wild Heerbrugg	Geodimeter	Cubic

- Store Coordinates - Records, as well as computes, coordinates.

- Input Known Parameters - Refers to keyboard input of reference information, such as back azimuth, starting coordinates, etc. this information is then used by other built in programs to perform computations.

- Display Raw Data - Provides for the review of raw measured and observed data.

- Collimation Correction - Determines the field instrument's collimation error and automatically applies it to measurements.

- Formatted Output to Printer (Without Aid of Computer) - The ability to print formatted readable field notes directly to a printer, without the aid of a computer. Typically, most data collectors provide an RS-232C interface and transmit a computerese type "COMS" output to the printer. A formatted output takes this one step further and identifies all measurements and observations with english headings, such as horizontal angle, slope distance, etc.

Programmability

The ability to change, or program, either the recording order of measured data (see measurement sequences above) or the function of the data collector.

- Program From Keyboard - Manually programmed from the keyboard of the data collector. Usually refers to changing measurement sequences only.

- Download From Computer - Programming from an office computer may be downloaded to the data collector.

- Number Of Programs That Can Be Stored - Usually, there are some memory limitations that restrict either the number and/or size (number of bytes) of additional programs that can be stored in the collector.

	Wild Heerbrugg	Geodimeter	Cubic
Store Coordinates			
Input Known Parameters			
Display Raw Data			
Collimation Correction			
Formatted Output to Printer			
Programmability			
Program From Keyboard			
Download From Computer			
Number Of Programs That Can Be Stored			

Item	Wild Heerbrugg	Geodimeter	Cubic
Linework			
Standard Types			
User Definable Types			
Spec. Repeat Pattern Lengths			
Plot Range of Points			
Plot Sets of Points			
Cross Hatch Areas			
Plot Scaled Lines			
Digitize Existing Drwgs.			

Linework

The ability to plot a variety of line types. Includes, the number of standard choices and capability to create additional line types. May include the ability to plot lines by specifying ranges of consecutive or blocks of non consecutive points. The ease with which this can be done is extremely important.

Optionally, may include the ability to graphically represent ground elevations, by plotting point elevations, contours, cross sections and profiles. While most drafting programs have limited 3D capabilities, they are primarily designed for 2 dimensional plan views. Any extensive 3D capabilities are usually reserved for specialized software, such as topographic modelling, road design and earthwork packages.

Tasks/Functions to look for include:

- Standard Types - Number of standard line types which a user may select. For example solid, dashed, centerline, etc.

- User Definable Types - Number of line types which a user may create and store for later use. For example fence line, railroad tracks, etc.

- Spec. Repeat Pattern Lengths - Can a user vary the repeat pattern length of line types? For example, short, or long, dashes.

- Plot Range of Points - Plots lines between a range of consecutive points. Useful for automatically plotting similar line types with similar attributes.

- Plot Sets of Points - Automatically plots a set (group, figure, layer etc) of non consecutive points. These sets are usually created in coordinate geometry. Useful for plotting similar line types, with similar attributes. For example, a boundary, centerline, R/W line, or lot perimeter may be described as a set and plotted with one command.

- Cross Hatch Areas - Highlights selected areas of the plot with cross hatching, shading, or special symbols.

- Plot Scaled Lines - Uses a digitizer to plot from a scale, rather than between coordinates. Useful for plotting scaled easement lines.

- Digitize Existing Drwgs. - Existing maps may be digitized and stored for later replotting. A plotter may have some limited digitizing features to orient existing maps on the plotter bed, but this usually requires a digitizing table and puck (digitizing site, with numeric keypad). May include the ability to trace contours and curves, as well as digitize the end points of straight lines.

- Calculate & Plot Contours - Calculates and plots user specified contour intervals between spot elevations. This can laboriously proceed on a point by point basis or be automatically done by the program.

- Draw Parallel Lines - Draws a line parallel to another line, without computing the end point coordinates. Useful for plotting easement and other lines that do not require coordinates to be staked in the field.

- Draws Lead In Arrows - Plots lead in arrows from annotation, or notes that are cast off from a line.

- Instant CRT Plot - Plots a line sketch on the screen as points are being computed or the plot file is being developed. Useful for checking your work as you proceed.

Annotation

The ability to automatically annotate lines or points with their parametric values. The values are computed by the program and placed at user specified locations. Tasks/functions to look for include:

- St. Line Parameters - Includes bearing/azimuth and distance.

- Curve Parameters - Includes arc length, chord length, tangent length, radius, central angle, deflection angle, etc.

- Point Parameters - Includes X Y Z coordinates, descriptors, point numbers, etc.

- Annotation Locations - The user specified position of the annotation for straight lines, curves and points. Often set up by menu selection, before the plot sequence is entered. Usually provides a choice of two or more locations. When your choice doesn't fit, program automatically puts information in a curve table, for later plotting. Some programs provide the capability to specify an alternate location. Digitizer based programs are, generally, more flexible than keyboard based programs.

- Size - User may specify the size of annotation by either an absolute value or a value relative to scale.

Wild Heerbrugg	Geodimeter	Cubic

Symbols/Figures

The ability to select, position and create point symbols and special figures. Building footprints, trees, manholes, etc. are examples. Using a table digitizer to create these is much faster than using a keyboard to enter coordinates or a plotter digitizer to digitize locations.

Tasks/Functions to look for include:

- Standard - Number of standard symbols/figures provided by the program. For example, point marks, tie marks, circles, squares, triangles, trees, etc.
- User Definable - Number of symbols that may be defined and stored for later use.
- Size - User may specify size of symbols/figures by either absolute values or values that vary with scale.
- Mirror Image Symbols/Figures - Flops over, or mirrors, symbols and figures. Useful for plotting standard building footprints.
- Specify Rotation - Specifies the rotation angle about a point of the symbol or figure.

Keyboard Text

Inputting, positioning and plotting special text, such as notes, street names, lot numbers, block numbers, etc. Different than annotation, as all text entry is manually input from the keyboard. User may vary the size, style and slant. Location is chosen by coordinate positions or with a digitizer. Some programs allow the user to plot a rectangular box where text is be located (includes annotation). Allows user to get a quick look at the plot and decide whether everything looks okay before a final drawing is attempted. May be done on the screen or plotter. Using a table digitizer to locate text is best.

Miscellaneous Functions

Includes program wide functions, not specific to annotation, keyboard text, or linework.

Tasks/functions to look for include:

- Vary Text Size With Scale - Selects text and/or annotation size in proportion to scale. When the plot scale is changed, all text is automatically changed to fit.
- Vary Text Ht./Width Ratio - Elongates, or squashes, text.

	Wild Heerbrugg	Geodimeter	Cubic
Symbols/Figures			
Standard			
User Definable			
Size			
Mirror Image Symbols/Figures			
Specify Rotation			
Keyboard Text			
Miscellaneous Functions			
Vary Text Size With Scale			
Vary Text Ht./Width Ratio			

- <u>Auto # Lots/Blocks</u> - Program automatically increments lot numbers once location is chosen. When used in combination with a digitizer, or with a program that automatically places the number at the center of the lot, this can be a very powerful tool.

- <u>Automated Legal Descriptions</u> - Facilitates plotting legal descriptions. May be as simple as a basic text editor, or as sophisticated as recalling common legal description terms, such as "to the point of beginning", "thence along a line", etc. May also be integrated with coordinate geometry, so that points may be entered and automatically converted to bearings and distances by the program.

- <u>Line & Paragraph Editors</u> - Allows text corrections on a line by line or paragraph by paragraph basis. Paragraph editor's are usually more flexible, because they contain some word processing functions and automatically reformat paragraphs.

- <u>Listing & Editing Plot Sequences</u> - Lists and corrects plot files (sequences). May be as tedious as changing every line, or as simple as making one change and having it reflected in the rest of the file. Some programs can search and replace plot instructions. For example: "search for all dashed lines and replace them with solid lines". This can be a very powerful editing tool. Copying standard plot sequences from one part of the file to another, can also be very useful.

- <u>Auto Replot Entire Drwg.</u> - Automatically replots the entire drawing. Useful when changing scales and orientation. Most programs can easily replot lines, points and annotation, but special text, north arrows and tables are sometimes manually located after the drawing is complete.

- <u>Orient/Rotate Plot</u> - Orients and rotates the location of the plot on the plotting surface. Usually requires a rotation point and X Y location from a corner of the plot surface, plus a direction of rotation, scale, overall plot dimensions, etc. All annotation and text should be automatically re-oriented to read properly.

- <u>Window Section of Plot</u> - Isolates and plots a section of the plot file.

- <u>Pens Supported</u> - How many pens does the program support. The more pens it supports, the less often you have to manually change pens.

	Wild Heerbrugg	Geodimeter	Cubic
Auto # Lots/Blocks			
Automated Legal Descriptions			
Line & Paragraph Editors			
Listing & Editing Plot Sequences			
Auto Replot Entire Drwg.			
Orient/Rotate Plot			
Window Section of Plot			
Pens Supported			

APPENDIX B

MILESTONE SCHEDULE

EVENT	DATE
TSS ROC	1978
MARKET SURVEILLANCE	OCT 1985
APPROVED O&O Plan	OCT 1986
DRAFT ACQUISITION STRATEGY	MAR 1987
Draft TEMP	MAR 1987
Draft ILSP	MAR 1987
INITIAL TIWG/ILSMT MEETING	MAR 1987
MARKET INVESTIGATION	MAR 1987
MARC/MARB	JULY 1987
MARKET INVESTIGATION TESTING COMPLETED	SEPT 1987
CONTRACTOR TEST REPORTS AVAILABLE	OCT 1987
IER (30 to 60 days after completion of testing and receipt of test reports)	DEC 1987 (tentative)
MILESTONE I/III IPR	FEB 1988
CONTRACT AWARD	JULY 1988
FAT	OCT 1988
IOC	MAR 1989

APPENDIX C

ENVIRONMENTAL DOCUMENTATION

Before testing can begin, the developer, as the proponent, must ensure that the Federal and DA requirements for documenting environmental considerations have been satisfied.

Life-Cycle Environmental Documentation. The developer must review the DA list of categorical exclusions (Reference C-1) to determine whether the development of the materiel is exempt from the requirement to prepare a Life Cycle Environmental Assessment (LCEA) or an Environmental Impact Statement (EIS). If the development of the materiel qualifies for a Categorical Exclusion (CX), then a Record of Environmental Consideration (REC) referencing the CX and stating that no extraordinary circumstances exist must be prepared. If the development of the materiel does not qualify for a CX, the appropriate life-cycle environmental documentation must be prepared (Reference C-2).

Existing Environmental Documentation. If the developer intends to use an existing environmental document to support follow-on development, such as a Product Improvement, an REC must be prepared to reference the existing document, provided that the existing document is still a current, accurate, and complete treatise on the pertinent environmental issues associated with the developmental item.

Pre-Testing Coordination. The developer should contact the Environmental Quality Control Coordinator at each TECOM Installation or Field Operating Activity where testing is contemplated, to ensure that the public notice requirements have been satisfied when the LCEA, or supplement to an existing environmental assessment, concludes that either a Finding of No Significant Impact or a Notice of Intent to write an EIS is appropriate.

REFERENCES

C-1. AR 200-2, Environmental Effects of Army Actions, 1 September 1981, and Change 1, 15 September 1982.

C-2. DARCOM Supplement 1 to AR 200-2, Environmental Effects of Army Actions, 26 February 1982.

TEST AND EVALUATION MASTER PLAN (TEMP)

for the

AUTOMATIC INTEGRATED SURVEY INSTRUMENT (AISI)

Part I - Description and Evaluation Plan

1. Mission of System. There is a need for the AISI in the Army by all elements of the topographic survey units, topographic and intelligence teams, and heavy engineer construction units. The primary operational deficiency with existing survey equipment is the lack of speed. On the Airland Battlefield, surveyors must rapidly collect, process, and assess survey data. Use of existing equipment causes survey projects to be completed in weeks and months instead of the hours and days which are the demands of real world requirements. The capability of topographic and construction units to complete field survey projects to obtain position, azimuth and elevation data is quantified in the 1983 Mission Area Analysis (MAA). The use of AISI will significantly increase the speed and accuracy of survey projects with the added benifit of a decrease in the number of soldiers required for each operation. In the data reduction phase, only two soldiers will be required for each 24-hour shift, instead of the current crew of five.

The AISI with a seven kilometer range will provide position data support for weapon systems, communications, intelligence gathering, and command and control activities. Construction survey units will use an AISI with a two kilometer range to perform surveys in support of construction projects, such as, airfields, roads, bridges, and major facility layouts. Since the AISI is planned for deployment in supprt of division, corps, and echelons above corps (EAC) activities, a similiar threat can be expected from direct and indirect fire, air attack, nuclear, biological and chemical (NBC), and electronic warfare as would be expected to the command and control elements of these echelons. Further threat can be anticipated from the use of convential and nuclear explosives that generate high-energy electromagnetic pluse (EMP) intended to damage electronic components in much the same way as would some of the directed-energy weapons. The AISI will perform a combat support and combat service support mission, and is not designed to overcome any specific threat implications.

The AISI is an electronic total station intended to supply the military surveyor with a single device with which to achieve all functions formally carried out with theodolites, tapes, and distance measuring devices. With the fielding of the AISI, the Wild T-2, Degree Reading, One Second, Theodolites; the Surveying Equipment, Distance Measuring, Electronic, Medium Range (SEDME-MR); the Theodolite Survey, 0.2 Second, with tripod and carrying case, (in part); the Alidade, Surveying, with plane table and tripod; the Target Set, Surveying; the Rod Level Philadelphia; and other ancillary equipment will be deleted from the inventory. The T-2, mil reading, Theodolites used by field artillery units will not be replaced.

2. System Description. The AISI is enclosed in a man portable, environmentally protected and ruggedized carrying case designed to withstand the rigors of the field environment. It will automatically perform horizontal and vertical angle measurement, horizontal and vertical distance measurement, and slope and zenith distance measurements. It has an onboard microcomputer to automatically calculate the above functions at the push of one or more buttons by the operator. The results of these functions are then displayed on the instrument panels, and can concurrently be routed to the portable data collector for retention and later use in the office for the data reduction phase. The data stored in the collector is transferred to an external microprocessor for direct printing by a printer and/or plotter, or, refinement with the use of commercial surveying software programs. Because of the different range requirements for engineer construction and topographic survey missions, two AISI's will be issued as: (1) Survey Set, Construction, Two Kilometers; and (2) Survey Set, Topographic, AISI, Seven Kilometers. The commercial microprocessor, software programs, printer, and plotter will be issued separately as set (3), Survey Set, Processing Station. Each of the sets will be type classified separately by purchase description. The Basis of Issue Plan (BOIP) will require one processing station for every three AISI's issued. The construction and topographic survey sets will include, besides AISI's, ancillary equipment, such as the electronic data collector, prisms, prism holders, carrying case, cables, etc.

a. Key Functions. The AISI is mounted on a standard military tripod and positioned accurately over a designated control point, then pointed at a target, which consists of a combination retro-reflector prism which is also mounted on a tripod or prism pole. After sighting the AISI onto the target/retro-reflector, the operator has the option of entering his choice of the data required, i.e., horizontal distance, slope distance, vertical angle, horizontal angle, difference in elevation, automatic recording, and various other data used by the field surveyor. The AISI will measure and reduce slope distance to the required accuracy by transmitting an amplitude-modulated infrared light beam signal to, and receiving the signal back from the retro directive prisms, and then by on board processing, compute and display the horizontal distance in feet or meters. The AISI will measure electronically both the horizontal and vertical angles and display the mean results, which are then sent to the data recorder for storage and later processing.

b. Interfaces. The Army surveying capability must include a "field to finish" system. Therefore, the AISI and its software programs must interface with the ~~Zenith~~ Z248 microprocessor, ~~printer, and plotter~~ currently used in the Army. The microprocessor with software will convert the raw field data into adjusted survey data which can then be printed and/or plotted as required. The AISI will use the Doppler Satellite Survey System and Global Positioning System for extension of prime control established by these systems. It will be used for alignment and updating position data of the Position and Azimuth Determining System (PADS), and other Intertial Navigation Systems.

c. Unique Characteristics. There are no unique AISI characteristics that necessitate special test requirements.

3. Required Operational Characteristics. The key required operational effectiveness and operational suitability characteristics were extracted from the O&O Plan and are shown below in this paragraph. Those considered critical to the ability of the AISI to accomplish the intended survey missions are identified by an asterisk. Thresholds and performance goals against which each required characteristic will be evaluated are also shown below.

OPERATIONAL CHARACTERISTIC	THRESHOLD/PERFORMANCE GOAL
a. *Mission	(1) Able to provide horizontal coordinates, elevations, azimuths, and hard copy output using field survey methods at the accuracy required for accomplishing the theater geodetic, topographic, construction, and artillery and missile fire missions

	Accuracy and time thresholds are shown in Part I, paragraph 5.b.
b. *MANPRINT (Probability of completion within thresholds =95%)	(1) Can be used by a crew of three topographic surveyors (MOS 82D), or three construction surveyors (MOS 82B). (2) Preparation time for movement=15 minutes. (3) Field setup time for distance measurement = 5 minutes. (4) Field setup time for direction measurement = 8 minutes. (5) Time to conduct distance data collection = 2 minutes. (6) Time to conduct direction data collection = 10 minutes (topo), 5 minutes (const). (7) Time to layout curves (per point) =1 minute. (8) Time to collect planetabling data = 1 minute. (9) During the data reduction phase, only one soldier required for each 12 hour shift. (10) Process field data in 3 to 5 minutes. (11) Less than 5 percent error in soldier performance of tasks while meeting specified time constraints. (12) Operable and maintainable by 5th percentile female through 95th percentile male soldiers who are dressed appropriately for intended environments of use.
c. Transportability	(1) Transportable in Army vehicles.
d. Night operations	(1) Will have sufficient illumination for night operations.
e. *Logistic Supportability	(1) The MOS 82D and 82B surveyors can perform the maintenance perscribed in the commercial operators manual in 15 to 30 minutes. (2) No new TMDE required. (3) Have an ruggedized carrying case

4. Required Technical Characteristics. The key required technical characteristics, which were extracted from the O&O Plan, and the thresholds and performance goals against which each will be evaluated, are shown below in this paragraph. Characteristics which are considered critical to the ability of the AISI to accomplish the intended survey missions are identified by an asterisk.

TECHNICAL CHARACTERISTIC	THRESHOLD/PERFORMANCE GOAL
a. *Accuracy and Range	(1) Will measure distances from 2m to 7Km with a digital output to 1mm with an accuracy of + or - (5mm + 5mm/km) +3 PPM. (2) LCD display readable in daylight or dark. (3) Built-in corrections for curvature refraction and slope. (4) Tracking mode with a responce time of 1 second or less. (5) An electronic compensator for mislevel of the instrument.(6) Ability to compensate for eccentricity of the instrument.
b. Distance measurement time	(1) After actuation of the power switch to the "ON" position, the time required for first distance reading shall not be more than 4 minutes; subsequent readings in not more than 6 seconds, on a fixed station.
c. *Angle measuring capability	(1) Electronic incremental reading of horizontal and vertical readout with accuracy of 1.0 seconds, and measuring time of < 0.5 seconds.
d. Operating characteristics	(1) Power source of both internal rechargeable battery & external 12 to 24 volt DC vehicular battery. (2) Telescope magnification of 30 to 40 power erect image. (3) Optical plumbing device. (4) Alidade plate level sensitivity = 20 seconds/2mm.

	(5) Illuminated reticle for night observations. (6) Minimum focus of 2 meters or less. (7) Tracking mode.
e. *Electronic recording capability	(1) Direct data recording and dumping. (2) RS232/V24 interface to computer system. (3) Preprogrammed field calculations and storage. (4) 60-Kb memory. (5) Alphanumeric keyboard. (6) 16-column display. (7) Minimum operating time of 16 hours. (8) Data storage and retention time of least 1500 hours
f. *External microprocessor capability	(1) Fully MS/DOS compatible with AISI and other peripherals. (2) Direct interface with the data storage device. (4) Software consisting of a full range of AISI compatible geodetic and topographic programs. (5) Power supply 110-220 volts AC with battery backup.
g. Plotter characteristics	(1) Be fully compatible with the microprossessor. (2)Work in minimum size format of 24 inches x 30 inches. (3) Have a multi-pen capability for different colors and pen sizes.
h. *Safety and Health	(1) Comply with ARs 385-10, 385-16, 40-5, 40-10, and Mil-Std-882B. (2) Will not present uncontrolled, catastrophic, or critical residual safety of health hazards. (3) No Category IA, IB, IC, ID, IIA, IIB, IIC, and IIIA risks. (4) Meet requirements of TB-MED 524, MIL-STD-1472, and ANSI Z136.1.
i. Human Factors Engineering	(1) Comply with requirements of MIL-STD-1472.

j. Secure Lighting

(1) All visable lighting shall be a blue-green color and otherwise conform to secure lighting standards.

The above characteristics pertain to both topographic and engineer construction AISI's. The following characteristics pertain only to the short range AISI to be used for engineer construction survey missions:

a. *Range

(1) From 2 meters to 2 Km with a digital output in feet or meters readable to 1mm or .005 foot.
(2) Ability to store and layout precomputed distances.

b. *Angle measurement

(1) Electronic incremental reading of horizontal and vertical readout with 30 seconds accuracy and less than 0.5 second measurement time.
(2) Ability to lay out precomputed right/left deflection angles.
(3) Capable of measuring and layout of vertical angles, zenith distance, and percent of slope.

c. Operating characteristics

(1) Capable of tilting to at least 100 percent slope (45 degrees) up and down. (2) Have software consisting of a full range of AISI compatable construction engineering programs.

5. Critical T&E Issues and Criteria. The following T&E issues and criteria were extracted from the IEP's prepared by USAES and TECOM. Critical issues are identified with an asterisk; the others are noncritical. Compliance with critical issues and criteria will be demonstrated during the market investigation testing and from commercial AISI manufacturer's and customer's usage data. Any remaining noncritical issues will be answered during First Article Tests and/or Follow-on Test and Evaluation (FOT&E).

a. Technical Issues

*(T-1) Issue: Does the AISI meet the performence requirements for topographic and construction surveys as specified in the AISI O&O Plan and the Topographic Support System ROC, during day and night operations, to include the following characteristics:

a. Minimum and maximum range;
b. Horizontal, slope, and zenith distance measurement accuracy;
c. Horizontal, and vertical angle measuring accuracy;
d. Optical capabilities?

Criteria: The AISI is required to perform the following mission profile: To provide horizontal, coordinates, elevations, azimuths, and hard copy output using field survey methods at the accuracy required for accomplishing the theater geodetic, topographic, construction, and artillery and fire missions.
Topographic characteristics desired are as follows:

a. Range of from 2 meters to 7 kilometers, with a digital output to 1mm with an accuracy of +/-5mm and +3ppm.
b. Tracking mode with a response time of 1 second or less.
c. Electronic incremental reading of horizontal and vertical readout with an accuracy of 1.0 seconds with a measuring time of less than 0.5 second.
d. Illumunated reticle for night operations; telescopic magnification of 30 to 40 power erect image for angle measurements; minimum focus of 2 meters or less for angle measurements.
e. Tracking mode.

Construction survey characteristics. The construction AISI should have the same capabilities as the topographic AISI with the following exceptions:

a. Range: From 2 meters to 2 kilometers with a digital output in feet or meters readable to 1mm or .005 foot.
b. Angle measurement: Electronic incremental reading of horizontal and vertical readout with an accuracy of 30 seconds with a measurement time of less than 0.5 second.

(T-2) Issue: Does AISI meet the mission requirements for operations, storage, and transporation in all the expected environments, to include nuclear EMP and can the AISI be decontaminated`?

Criteria: The AISI will be expected to be used in the Hot, Basic, and Cold climatic design types as defined by AR 70-38, table 2-1, and MIL-STD-210B. The AISI will have the same transportability characteristics as present transportable (mobile) survey instruments. Field parties normally travel in 5/4 ton CUCV vehicles, survey company personnel in 1/4 ton trucks, and the survey section of the Topographic Support System in a 5-ton tractor vehicle. AISI equipment should not be any more susceptible to military environmental conditions than currently fielded survey equipment.

*(T-3) Issue: Are the measured data automatically calculated, displayed, stored, and available for transfer and is the AISI compatible with software and external microprocessors for further production of survey functions?

Criteria: Calculation functions.

a. Automatically performs horizontal and vertical angle measurements, horizontal distance measurement, and slope and distance measurements.

b. Preporgrammed field calculations and storage.

c. Built in corrections for curvature, refraction, and slope.

d. Ability to compensate for eccentricity of the instrument.

Data storage and display functions:

e. 60 kilobyte memory.

f Alphanumeric keyboard.

g. 16 column display.

h. Minimum operating time of 16 hours.

i. Direct data recording and dumping.

j. Ability to store and lay out precomputed distances.

k. Ability to lay out precomputed right/left deflection angles.

l. Capable of measuring and layout of vertical angles, zenith distance, and percent of slope.

m. Direct data recording and dumping.

n. LCD display readable in daylight or dark.

Data transfer and compatibility with microprocessors and software designed for processing of surveying functions: RS232/V24 interface to computer system.

*(T-4) Issue: Do the available microprocessors, software, and

peripheral equipment interface with AISI to provide the required printouts and plots of surveying functions?

Criteria: External microprocessor capabilities.

a. Fully MS/DOS compatible with AISI and other peripherals.

b. Direct interface with the data storage device.

c. Direct interface to a printer and plotter.

d. Must be fully compatible with microprocessor.

e. Software package shall consist of a full range of available, AISI compatible geodetic, topographic, and construction engineering programs.

Plotter characteristics:

a. Must be fully compatible with microprocessor.

b. Must work with a minimum size format of 24 by 30 inches.

c. Should have a mulit pen capability for different colors and pen sizes.

*(T-5) Issue: Does the AISI meet the established reliability requirements and, if not, what impact will this have on mission requirements?

Criteria: Quantitative reliability requirements will be established and included when the RAM Rationale Report (RRR) is completed. However, the AISI must have a high probability of completing the Operational Mode/Mission Profile requirements of the O&O Plan as described below:

a. The topgraphic surveyor in wartime furnishes the field artillery weapons positioning and azimuth control on a continuing basis 12 hours each day, 7 days a week. Peace time normally is solidifying and densifying control on an as needed basis 10 hour days and 5 day weeks.

b. Construction surveyors in wartime run route reconnaissance, surveying bridges, roads, airfields, culverts, etc., 12 hour days, 7 day weeks. During peace time operations, the only difference is the week is shortened to 10 hour days and 5 day weeks.

*(T-6) Issue: Does the logistice supportability plan for the AISI system (AISI with support equipment and software) satisfy mission needs and what is the impac'''t on the overall logistics supportability if any of the elements listed below are not met?

a. End Item Requirements.

b. Supply Support.

c. Technical Data/publications.
d. Support and Test Equipment.
e. Manpower and Personnel, Training and Training Devices.
f. Transportation and Handling.

Criteria: Repair parts will be authorized in adequate quantities and diversity at the appropriate maintenance levels. Repair parts will be consistent with the Maintenance Allocation Chart (MAC), Repair Parts and Special Tools List (RPSTL), and skills required to install and align parts.

The technical data/equipment publications shall adequately reflect the system they support. The technical data/equipment publications shall be easily and completely understood by maintenance personnel.

The special/common tools, and support and test equipment shall be necessary and adequate for the performance of all authorized maintenance tasks at each level of maintenance. The design of the system should permit the use of common tools whenever possible.

The skill levels shall be appropriate for maintenance. The number of personnel shall be adequate for maintenance. The training provided shall be sufficient to impart the necessary skills for maintenance. The operators must be able to service the AISI in 15-30 minutes. The AISI must also meet the maintenance ratio (MR) requirements that will be established in the AISI RRR.

The AISI shall have the same transportability requirements as the current survey equipment.

*(T-7) Issue: Does the AISI meet the man-machine interface requirements of MIL-STD-1472 and are the human factors engineering design and operational characteristics adequate to enable MOS-82D, 41B, 35E qualified soldiers appropriately clothed for the environments of interest to permit effective operation and maintenance?

Criteria: The AISI when used in the field data collection phase of operations will be utilized by a crew of three topographic surveyors (MOS 82D) or construction surveyors (MOS 82B) similar to current operations. When the AISI is used in the data reductinon phase, only one person should be required for each 12-hourshift, as opposed to the five personnel required to provide quality control and supervision for the manual processing of field data in a 24 hour time period of operations.

The AISI will have systems, health assessment, and human factors evaluations as required.

Maintenance personnel for the AISI will be Topographic Instrument

Repair Specialist (MOS 41B) and the Special Electronic Devices Repairer (MOS 35E) as presently assigned to engineer topographic units and corps/division maintenance units.

All HFE data shall comply with MIL-STD-1472 and any other applicable requirements documents. The AISI shall comply with the human factors engineering program requirements of AR 602-1 and MIL-H-46855, and shall be designed in compliance with applicable environmental protection requirements of AR 200-2, and AR 200-2.

*(T-8) Issue: Have the safety and health hazards associated with AISI operation, maintenance, transportation, and storage been controlled to an acceptable level?

Criteria: The AISI shall comply with the system safety and health hazard program requirements of ARs 385-10, 385-16,, 40-5, 40-10, and MIL-STD-882B. The AISI shall not present uncontrolled, catastrophic, or critical residual safety or health hazards. Safety deficiencies, defined as Category IA, IB, IC, ID, IIA, IIB, IIC, and IIIA risks, shal be eliminated or controlled by design whenever feasible.

The AISI design must comply with the intent of MIL-STD-454, requirement 1 (safety), for operator and maintainer safety.

Ionizing radiation sources shall not be used without prior notification and approval. When use is necessary, the source(s) shall be controlled IAW regulatory and statutory requirements. Non-ionizing radiation sources (e.g., laser or other directed energy device) used in design must be approved, and should not present a hazard to personnel during operation (e.g., eye safe laser).

(T-9) Issue: Does the AISI meet the MIL-STD-461B requirements for electromagnetic interference/electromagnetic compatibility?

Criteria: The alctromagnetic interference emission and susceptibility characteristics shall conform to MIL-STD-461, methods RE02 for radiated and CE03 for conducted tests, for Class B equipment. The frequency spectrum shall be from 0.014 through 1 GHz during the radiated tests and from 0.020 through 50 MHz during the conducted tests with the following exceptions:

(a) Broadband radiated emissions (RE02) at 0.3 MHz and 0.7 MHz shall be increased by 5 dB and,

(b) Broadband radiated emissions (RE02) at 150 MHz shall be increased 6 dB above the requirements of MIL-STD-461 (SEDME

Specification, MIL-STD-53046.

(T-10) Issue: Does AISI meet the physical design characteristics such as weight, size, and rigidity?

Criteria: Commercially available shapes are acceptable. As a guide for comparision with similar systems, the maximum weight of the distance meter, exclusive of tripods, but including primary power source, shall not exceed 25 pounds (11.3kg). The total system weight shall not exceed 50 pounds (22.7 kg). (SEDME letter Requirement)
AISI design should include the following characteristics:

a. An electronic compensator for mislevel of the instrument.
b. Impact-resistant carrying case and instrument test and repair kit.
c. Capable of tilting to at least 100 percent slope (45 degrees) up and down.

(T-11) Issue: Is the electric power source acceptable for reliable AISI operation in compliance with the operational mode summary/mission profile?

Criteria: The AISI will operate from an internal, rechargeable battery and external 12 to 24 volt DC vehicular battery. The external microprocessor should have a power supply 110-220 volts AC with battery backup to prevent loss of data if primary powere interrupted.

(T-12) Issue: Is the AISI compatible with the Army Standard equipment that it is required to interface with?

Criteria: The AISI shall be compatible with the standard U.S. Army tripods and tribachs. The AISI will use the Doppler Satellite Survey System and Global Positioning System for extension of prime control established with these systems. It will be used for alignment and updating position data of the Position and Azimuth Determining System and other Inertial Navigation Systems. The microprocessor will allow direct access to data base allowing for rapid dissemination of the information contained in them.

b. Operational Issues

*(O-1) Issue: Does the AISI effectively perform topographic and construction survey tasks in an operational environment?

This issue will evaluate the capability of the AISI to effectively perform topographic and construction survey tasks when employed by representative users IAW the operational mode summary/mission profile (OMS/MP). An assessment will be made of the AISI's performance in climatic design types hot and basic IAW AR 70-38. Testing will be conducted IAW the OMS/MP and test settings described in the test support package (TSP). Testing will be conducted in ambient weather conditions, during day and night/limited visability conditions expected on the battlefield. Data gathered will be used in a baseline comparison with current survey equipment.

Criteria: The assigned crew using the AISI will perform the following tasks within the time and accuracy constraints specified 95% of the time:

TASK		ACCURACY	TIME
1. Preparation for movement		N/A	15 min
2. Preparation for field operations (setup)			
a. *Distance Measurement*		N/A	5 min
b. Direction Measurement (horiz & vert)		N/A	8 min
3. Conduct data collection			
a. Distances		+/-5mm +3ppm	2 min
b. Directions (horiz & vert)	(Topo)	+/-1 sec	10 min
	(Const)	+/-30 sec	5 min
c. Layout curves (per poiint)		+/-.0242ft per 1000ft	1 min
d. Planetabling (per point)		+/-.0242ft per 1000ft	1 min
4. Process field data (Topo) position closure ≤1:20,000			* 3-5 min
(Const) position closure ≤1: 5,000			* 3-5 min

*Dependent upon amount of stations in traverse scheme.

*(0-2) Issue: Does the AISI provide adequate data transfer capability? This issue will evaluate the capability of the AISI to directly record measured data and transfer that data from its microcomputer to the

data recorder and use that data to perform survey layouts. Specifically, this issue will evaluate the capability to "dump" or transfer electronic data via the data recorder and a RS232/v24 interface to an external microprocessor.

Criteria: The AISI, when employed by representative users IAW the OMS/MP will be able to record data in the data collector and transfer that data to the external microprocessor with 90% fidelity, 95% of the time. Representative users will be able to transfer data from the external microprocessor to the data recorder and with that data, use the AISI to layout precomputed distances and deflections with 90% fidelity, 95% of the time.

*(O-3) Issue: Does the AISI demonstrate adequate RAM for operational mission requirements? Data will be collected to determine the AISI's demonstrated RAM characteristics, and to identify potential availability and maintainability problems. Operational RAM characteristics of the AISI will be evaluated as the system is exposed to a variety of environmental conditions while conducting operational missions IAW the OMS/MP. Reliability, maintainability, and logistic support data will be collected and analyzed, and the impact on system readiness objectives and/or operational availability (Ao) assessed.

Criteria: MTBOMF for the AISI must equal or exceed TBD hours. The maintenance ratio for the AISI will not exceed TBD maintenance manhours/hours of operation. Ao for the AISI will be TBD or greater. (NOTE: RAM parameters will be furnished by USAES from the approved RAM rationale.)

*(O-4) Issue: Are there any safety or health hazards associated with the AISI? This issue will identify and assess safety and health hazards during all phases of testing to include time in storage, transport, maintenance, and operation. All safety and health hazard descepancies will be recorded and categorized IAW MIL-STD 882B.

Criteria: The AISI will not contain any uncontrollable safety or health hazards. The AISI design will comply with applicable safety requirements IAW AR 385-10, 385-16, 40-5, 40-10, MIL-STD 454 and TB MFD 524.

*(O-5) Issue: Is AISI designed for efficient and effective logistics

support? This issue is designed to assess the commercial end items for their logistic support requirements. Areas of consideration are requirements for and availibility of common and special tools, TMDE, repair parts, packaging, handling, storage, facilities, supply/provisioning, and standardization. Also considered are commercial operational and maintenance manuals. The frequency and type of logistic-related test incidents will form the basis for subjectively assessing the adequacy of the commercial logistic base.

Criteria: Repair parts and warranties from the manufacturer will be specified and must support the system at all levels of maintenance when fielded. The supply and maintenance organization will be competely described and the responsibility and work flow for each level of supply and maintenance will be clearly defined in the MAC. Integrated logistic support responsibilities, including maintenance and supply will be allocated to the proper level consistent with existing supply and maintenance procedures as determined by TOE. Requirements for supply and maintenance facilities will be consistent with current Army facilities, capabilities and allocations.

(O-6) Issue: Is the technical documentation for AISI accurate, comprehensive and effective? During testing, test players will be observed while performing operator, maintainer, and supervisor tasks using commercial manuals. Accuracy, comprehensiveness, and effectiveness will be assessed. Comments will be provided in the following areas:

a. Portions of text that are not clear, comprehensive, concise, or accurate.

b. Portions of text that operators, mainainers, and supervisors cannot adequately use, or that are unnecessary, or inappropriate.

Criteria: The AISI technical documentation and other software must correctly describe each of the critical task requirements. Ninety-five percent of trained representative military users, using the technical documentation, will be able to perform 100% of the critical tasks. The Reading Grade Level (RGL) of all technical documentation and training manuals will be within +/- one RGL for the particular MOS.

(O-7) Issue: Does the training program adequately prepare the representative soldier to use and maintain the AISI in an operational environment? The intent of the evaluation is to assess the training as outlined in the individual and collective training plan (ICTP), and as representative soldier to estabilished performance standards. Pretest effectiveness by a comparison to post-test skills. Demographic data on test players will be gathered and test players' profiles compared to representative population proviles obtained from the USA Soldier Support Center. Sources of tasks, conditions and standards identified in the ICTP will be used as the basis for the training evaluations. The entire training package will be assessed and trainer and tester input will be solicited to determine adequacy of training devices, manuals, aids, and other material. Training aids or devices will be evaluated for their effectiveness and ability to influence training transfer. Individual performance will be assessed during normal conduct of the test. Tasks that players have particular difficulty with will be reported and the training program for those tasks, including the performance standards, will be reassessed. Tasks necessary for operation and maintenance that were omitted from the training plan will be reported. A subjective determination of the efficiency and effectiveness of the training program will be made using QQPRI obtained during the test.

Criterion: Upon completion of training, 95% of the representative soldiers will be able to perform all of the critical tasks identified in the TTSP to prescribed standards.

(O-8) Issue: Can the AISI be transported by all required modes? This issue addresses the transportability characteristics of the AISI. Due to the small size and weight, it is not anticipated that the AISI will have transportability limitations. However, the ability of the AISI to withstand the rigors of transport by vehicle and backpack must be evaluated.

Criteria: AISI will be safely transportable within the using units existing TOE vehicles. The assigned crew will be able to properly package the AISI for transport. The ruggedized carrying case will protect the AISI from damage during normal transport. The AISI will be man portable in its carrying case and able to be backpacked by the assigned crew.

(O-9) Issue: Is the AISI adequately designed with requard to sound human factors engineering (HFE) principles? The issue addresses the AISI design with regard to human factors engineering principles when the system is employed in an operational environment by representative users. Testers will report HFE problems as they occur.

Criteria: The AISI shall meet the human factors engineering requirements of AR 602-1 and MIL-H 46855. Personnel must be able to set-up, operate, and store the AISI in its case while wearing cold weather clothing.

Part II - Program Summary

1. General. The requirement for the AISI was identified in the Topographic Support System (TSS) ROC in 1978, however, at that time only one manufacturer was known to produce such an instrument so the procurement was put off. The deficiency was again identified in the May 1983 Combat Support, Engineering and Mine Warfare, Mission Area Analysis.

The AISI Acquisition Strategy calls for an NDI-Category A procurement. A market analysis is being conducted, which includes both a market surveillance and a market investigation. The completed market surveillance has identified industries with the technical capabilities and capacities to produce the AISI, and provided the information necessary to conduct a more thorough market investigation. The market investigation, which includes the gathering of test and performance data from commercial manufacturers and customers and some limited T&E by the Government, is being conducted in order to verify that commercial AISI's, satisfy technical and operational requirements and are compatible with the microprocessor, printer, and plotter currently in Army Table of Distribution and Allowances (TDA's). The results of the investigation and the Independent Evaluation Reports (IER's) will be the basis for type classification of a generic commercial AISI with both range capabilities and the processing station. No further testing is planned prior to contract award. Three Line Item Numbers (LIN's) will be used to identify the three survey sets. The Milestone I/III, IPR is scheduled for the 2nd Qtr FY 88 and the production contract award is scheduled for the 2nd Qtr FY 89.

Two step Sealed Bids will be used with a performance specification and result in Full and Open Competition for a firm fixed-price contract for the three survey sets, and will include commecial manuals, provisioning documentation, spares/repair parts, maintenance support, training and training materials, and warranties. This procurement requires two step sealed bidding to determine the acceptability of the supplies and services offered. A Total Life Cycle Competition Strategy (TLCCS) is planned for this acquisition program. The production contract will be a requirements type contract to cover FY 89 and FY 90 buys. Warranty provisions of the contract will require a manufacturer's warranty of parts and labor of at least one years duration for each AISI delivered; additional coverage is desired. Contractors will be required to identify duel sources of supply for spares.

2. Management.

a. Overview. TROSCOM is designated as the readiness command and procuring activity for the construction, topographic, and processing station survey sets. The program is being managed by the Belvoir RD&E Center, Directorate for Combat Engineering, Combat Construction Division as the technical proponent on behalf of the USAES, representing the Combat Developer.

b. T&E Responsibilities. Belvoir has funded an engineering services contractor to develop the test plan and conduct the market investigation testing. Independent Evaluation Plans (IEP's) prepared by TECOM and USAES are being used as the guides for the data collection effort and testing. A TIWG has been formed to guide the conduct of T&E and the first TIWG meeting was held on 29 April 1987. The members are representatives from the following agencies:

MEMBER	AGENCY
TIWG Chairman/Materiel Developer	BelvoirRD&E Center
Combat Developer/User/Trainer	TRADOC/USAES
Technical Tester	TECOM
User Tester	Armor Engineer Board
Technical Independent Evaluator	TECOM
Operational Independent Evaluator	USAES
Logistician	LEA

3. Integrated Program Schedule

EVENT	DATE	RESPONSIBLE AGENCY
ROC Approved	2Q FY 76	TRADOC
Draft O&O Plan	2Q FY 85	TRADOC
Market Surveillance	1Q FY 86	Belvior RD&E Center
Final O&O Plan	4Q FY 86	TRADOC
Draft AS	2Q FY 87	Belvoir RD&E Center
Draft TEMP	3Q FY 87	Belvoir RD&E Center
Draft ILSP	3Q FY 87	Belvoir RD&E Center
TIWG/ILSMT	3Q FY 87	Belvoir RD&E Center
Operational IEP	3Q FY 87	USAES
Technical IEP	3Q FY 87	TECOM
Market Investigation	3Q FY 87	Belvoir RD&E Center
MARC/MARB	4Q FY 87	Belvoir RD&E Center
Final AS/TEMP/ILSP	4Q FY 87	Belvoir RD&E Center
BOIP/QQPRI	4Q FY 87	Belvoir RD&E Center
Operational IER	1Q FY 88	USAES
Technical IER	1Q FY 88	TECOM
Purchase Specification	2Q FY 88	Belvoir RD&E Center
IEP's Updated	2Q FY 88	TECOM/USAES
Milestone I/III IPR	2Q FY 88	Belvoir RD&E Center
Acquisition Plan	4Q FY 88	TROSCOM
Contract Award	2Q FY 89	TROSCOM
PAT&E/FAT	4Q FY 89	TROSCOM
Technical IER	1Q FY 90	TECOM
Materiel Release	1Q FY 90	TROSCOM
FUE	2Q FY 90	TROSCOM
FOT&E	2Q FY 90	Armor Engineer Board

Figure 1 shows the integrated time sequencing of the major program milestones.

4. Intergrated Test Schedule and Data Source Matrix. See Annex 1, (Objectives, scope, schedule, and location of First Article Tests (FAT) and Follow-on Test and Evaluation (FOT&E) are yet to be determined.

AUTOMATIC INTEGRATED SURVEY INSTRUMENT (AISI)
MAJOR PROGRAM MILESTONES

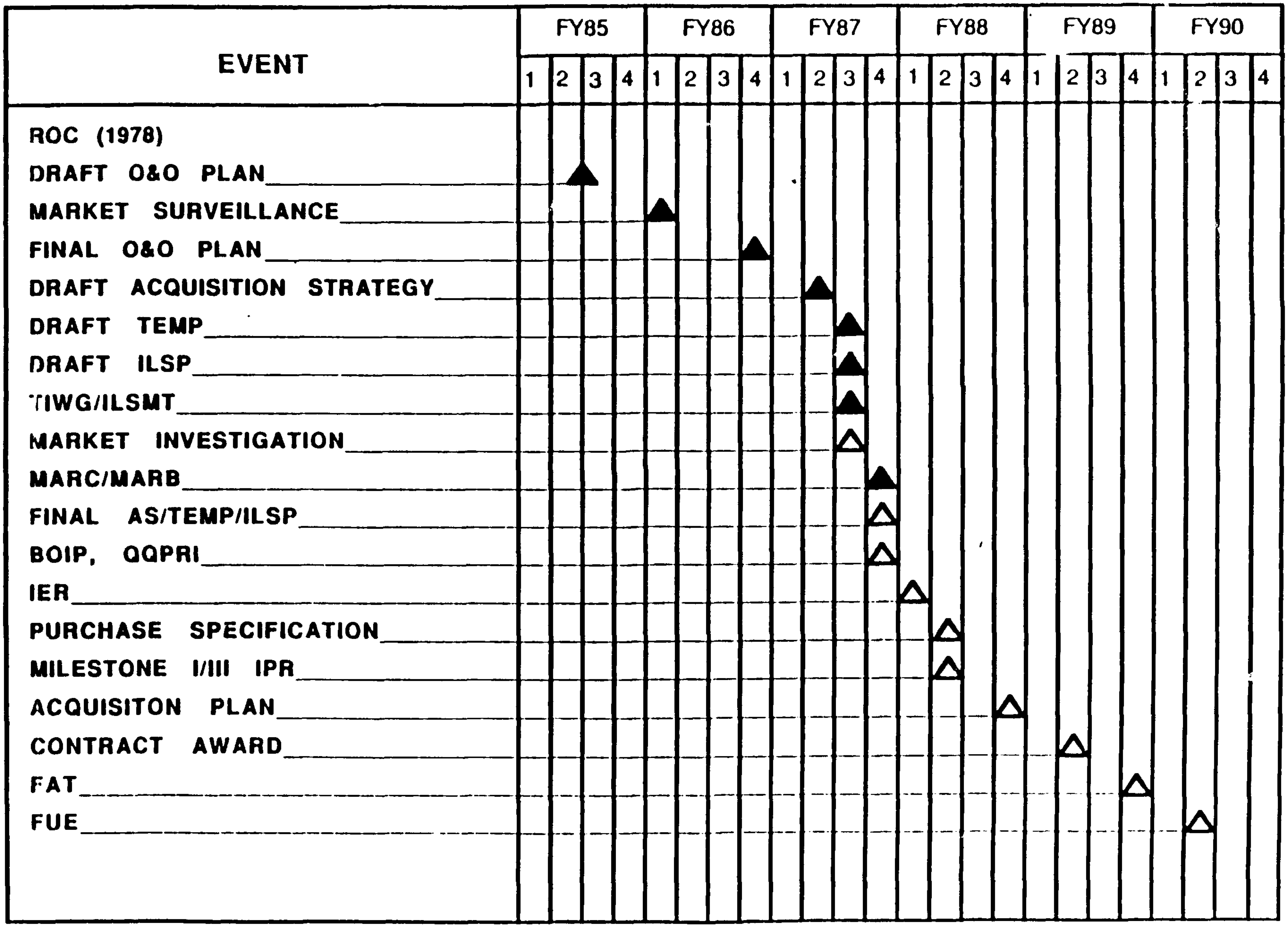

FIGURE 1

Part III - DT&E Outline

1. Critical T&E Issues. Technical independent evaluation issues for the AISI have been provided by TECOM and are presented in Part I, paragraph 5.a of this TEMP. TECOM will provide a Technical Independent Evaluation Report (IER) which will answer the technical issues and will be based on testing conducted during Market Investigation. The issues are summarized as critical technical characteristics listed below:

a. Meet technical performance requirements for topographic and for construction survey operations.
b. Meet mission requirements for operation, storage, and transportation in all expected environments.
c. Meet required accuracy to measure, store, reduce, and transfer field data for processing for survey functions.
d. Demonstrate AISI interface capability with required equipment.
e. Demonstrate required reliability.
f. Meet logistic supportability requirements.
g. Meet human factors engineering and safety requirements.
h. Meet EMI/EMC requirements.
i. Physical design characteristics.
j. Availability of power source for field operation.
k. Demonstrate compatibility with Army standard tripods and tribachs.

2. DT&E to Date. The testing of three different commercial AISI's, and the microprocessor, printer, and plotter currently in Army TDA's is currently being conducted by an independent contractor who has also provided the test support package. The test plan includes procedures for the full range of environmental testing and performance demonstrations to include human factors engineering, health and safety, and RAM, with pass and fail criteria.

3. Future DT&E. A First Article Test (FAT) will be conducted as part of the Production Acceptance Test and Evaluation (PAT&E) in accordance with the quality assurance provisions of the procurement documentation in order to verify that the AISI meets performance specifications. When developed, the quality assurance provisions will be coordinated with TECOM and USAES and the FAT added to the Integrated Test Schedule and Data Source Matrix (Annex 1). The plan for FAT will be prepared by the contractor and approved by the Government. The contractor conducted FAT will be witnessed by the Government.

4. Preproduction Qualification Test and Evaluation (PPQT&E). PPQT&E is not appropriate for NDI-Category A (off-the-shelf) procurements. The manufacturer will be able to propose his off-the-shelf AISI to the RFP

5. Production Qualification Test and Evaluation (PQT&E). PQT&E in the form of production acceptance tests will be performed by the contractor at the contractor's facility on each AISI procured. The tests, which will be witnessed by DCAS, are summarized as follows:

a. Manipulate all moveable parts and check for freedom of movement and noninterference with other parts in various operating positions throughout their operating range.

b. Fit or attach all accessories and check for functionality as specified.

c. Check the levels for freedom of movement to determine if the bubble remaines within the graduations and if the bubble ends of the coincidence level remain visible.

d. Rotate about horizontal and vertical axes, and check the illumination system for uniform and steady operation.

e. Check telescope focus for uniform and clear focus around each entire circle.

f. Check parts, components, and accessories for damage.

6. Software Verification and Validation. AISI's, in conjunction with personal computers and special surveyor's software programs are being used today by civilian construction and geodetic surveyors in the performance of their respective tasks. Given that similar construction and geodetic surveying tasks are conducted by military surveyors, the AISI and software will work for them as well. The system hardware consists of a Zenith 248 MS-DOS, and IBM compatible microprosessor with a 20 megabyte hard disk, and a floppy disk drive, printer and plotter. Software types for recording measurements and processing data are commercial off-the- shelf items. This external microprocessor system and available software programs will be verified and validated to ascertain if the capabilities, as required by the O&O Plan, can be met. The external microprocessor and software capabilities to be substantiated are:

a. Fully MS/DOS compatible with AISI and other peripherals.
b. Direct interface with the data storage device.
c. Direct interface to a printer and a 24 X 30 inch plotter.
d. Software package consisting of a full range of AISI compatible geodetic and topographic programs.

7. Special Retest Requirements. There are no known retest requirements.

8. Critical Resources. No critical test resources have been identified.

Part IV - OT&E Outline

1. Critical OT&E Issues. Critical OT&E issues were provided by the USAES and are identified in Part II, paragraph 5. b of this TEMP. Answers to OT&E issues will be demonstrated during the market investigation. Any unresolved issues will be further evaluated during FOT&E. An independent evaluation will be conducted by USAES and the results documented in their IER. In summary, the operational issues which are critical to the mission performance of the AISI are as follows:

a. Does the AISI effectively perform topographic and construction survey tasks in an operational environment?

b. Does the AISI provide adequate data transfer capability?

c. Does the AISI demonstrate adequate RAM for operational mission requirements?

d. Are there any safety or health hazards associated with the AISI?

e. Is AISI designed for efficient and effective logistics support?

2. OT&E to Date. The testing of three different commercial AISI's, and the microprocessor, printer, and plotter currently in Army TDA's is currently being conducted by an independent contractor. The test plan includes procedures for the full range of environmental testing and performance demonstrations to include human factors engineering, health and safety, and RAM, with pass and fail criteria. Performance demonstrations is being closely monitored by soldiers from the Army Engineer Center.

3. Future OT&E. FOT&E of the first AISI's issued and of the system support packages provided for each is planned in order to answer any issues unresolved after the market investigation. The issues and resources required for the FOT&E are not yet determined.

4. Critical Resources. No critical test resources have been identified.

Part V Special Test Resoures. One each of three different models of AISI's have been procured and provided as GFE to an independent contractor for market investigation testing. They are the: Cubic Precision model T1A, Geodimeter Inc., System 440; and the Wild Heerbrugg, Model T2000. In addition, the Zenith 248 microprocessor, printer, plotter currently in Army TDA's, and the commercial survey software programs have been provided as GFE for evaluation along with the three AISI's. Government facilities have been provided to the contractor for tests. All other test resources, to include a test support package, are being provided by the contractor. The testing and test support package was funded by the Belvoir RD&E Center. No further testing is planned proir to contract award. The cost for FAT will be quoted as a separate line item in the production contract. The funds required for FOT&E have yet to be determined.

Part VI Bibliography of Test Plans and Reports

1. Operational and Organizational (O&O) Concept for the Topographic Support System (TSS).

2. Required Operational Capability (ROC) for theTopographic Support System (TSS).

3. Market Surveillance Report.

4. Operational/Environmental/Suitability Test Plan For The Automated Integrated Surveying Instrument (AISI).

INTEGRATED TEST SCHEDULE
AND
DATA SOURCE MATRIX

ITEM	TEST TITLE	TEST OBJECTIVE	TEST SCOPE	TEST CONFIG.	TYPE OF DATA	SCHEDULE	LOCATION	TFC RQD	PARTICIPANTS: AMSAA	TECOM	OTEA	TRADOC	LEA	LOGC	BELVOIR	CRITERIA: MET	NOT MET
AISI	MARKET INVESTIGATION	RAM: T-5, 0-3	200 MISSIONS/ 300 HOURS	OFF-THE-SHELF AISI, PROCESSOR, PRINTER, PLOTTER	FAILURE REPORTS, PASS & FAIL CRITERIA	3QFY87	FT. BELVOIR ERG			E		E,O	E		R,M		
	"	SAFETY/HEALTH: T-8, 0-4	OBSERVATION 10 READINGS, ANALYSIS	"	SAFETY & HEALTH HAZARDS ASSESSMENT REPORT	"	"			E		E,O	E		R,M		
	"	TRANSPORTABILITY T-2, T-12, 0-8	SHOCK & VIBRATION TESTS	"	[illegible]LURE REPORTS, PASS & FAIL	4QFY87	CONTRACTOR FACILITIES			E		E,O	E		R,M		

REMARKS

TFC KEY
C-CERTIFIER
C1-PARTICIPANT
C2-MONITOR FOR EVALUATION
C3-CERT. REPORT ONLY
C4-OBSERVE ONLY
BLANK-NONE

TEST KEY
R-RESPONSIBLE FOR TEST
P-PARTICIPANT IN TEST
M-MONITOR TEST FOR EVALUATION
E-EVALUATION OF DATA ONLY
O-OBSERVE ONLY
BLANK-NONE

INTEGRATED TEST SCHEDULE
AND
DATA SOURCE MATRIX

ITEM	TEST TITLE	TEST OBJECTIVE	TEST SCOPE	TEST CONFIG.	TYPE OF DATA	SCHEDULE	LOCATION	TFC RQD	PARTICIPANTS: AMSAA	TECOM	OTEA	TRADOC	LEA	LOGC	BELVOIR	CRITERIA: MET	NOT MET
AISI	MARKET INVESTIGATION	ACCURACY, RANGE AND TIME: T-1, 0-1, 0-9	FIELD 10 READINGS	COMMERCIAL OFF-THE-SHELF AISI; ARMY STD ZENITH Z248 MICRO-PROCESSOR, PRINTER, & PLOTTER	FAILURE REPORTS	3QFY87	7KM RANGE-MANASSAS, VA 900 METER RANGE-FT. BELVOIR ENGINEER PROVING GROUND (EPG) CIRCLE ACCURACY-DEFENCE MAPPING SCHOOL			E		E,O	E		R,M		
"		OPERATING FEATURES: T-1, T-3, T-4, T-9, T-10, T-11, T-12	FIELD OBSERVATION 10 READINGS, ANALYSIS, INSPECTION	"	FAILURE REPORTS	3QFY87 4QFY87	BUBBLE, THERMOMETERS, ALT BAROMETERS, ACCURACY-NATIONAL GEODETIC SURVEY			E		E,O	E		R,M		

REMARKS 1) Three different model AISIs are being tested.
They are the : 1. Cubic, TIA
2. Geodimeter, 440
3. Wild T2000

All information on this schedule and matrix pertains to all [illegible]

TFC KEY
C-CERTIFIER
C1-PARTICIPANT
C2-MONITOR FOR EVALUATION
C3-CERT. REPORT ONLY
C4-OBSERVE ONLY

TEST KEY
R RESPONSIBLE FOR TEST
P PARTICIPANT IN TEST
M MONITOR TEST FOR EVALUATION
E EVALUATION OF DATA ONLY
O OBSERVE ONLY

DATA SOURCE MATRIX

ITEM	TEST TITLE	TEST OBJECTIVE	TEST SCOPE	TEST CONFIG.	TYPE OF DATA	SCHEDULE	LOCATION	TFC RQD	PARTICIPANTS: AMSAA	TECOM	OTEA	TRADOC	LEA	LOGC	BELVOIR	CRITERIA: MET	NOT MET
AISI	MARKET INVESTIGATION	ENVIRONMENTAL: HIGH TEMP SOLAR-RADIATION STABILITY HUMIDITY LOW TEMP RAIN FALL SHOCK VIBRATION SECURE LIGHTING MAGNETIC EMI SAND & DUST IR; T-2, 0-1, T-12	VARIED DAW MIL STD'S TEST PLAN AVAILABLE AT TIWG MEETING LAB TESTING	OFF-THE-SHELF AISI, PROCESSOR, PRINTER, PLOTTER IN RUGGEDIZED CASES	FAILURE REPORTS PASS & FAIL CRITERIA	3QFY87 4QFY87	NATIONAL TECHNICAL SYSTEMS, HARTWOOD, VA CONTRACTORS FACILITIES			E		E,O	E		R,M		

REMARKS

TFC KEY
C-CERTIFIER
C1-PARTICIPANT
C2-MONITOR FOR EVALUATION
C3-CERT. REPORT ONLY
C4-OBSERVE ONLY
BLANK-NONE

TEST KEY
R-RESPONSIBLE FOR TEST
P-PARTICIPANT IN TEST
M-MONITOR TEST FOR EVALUATION
E-EVALUATION OF DATA ONLY
O-OBSERVE ONLY
BLANK-NONE

INTEGRATED TEST SCHEDULE
AND
DATA SOURCE MATRIX

ITEM	TEST TITLE	TEST OBJECTIVE	TEST SCOPE	TEST CONFIG.	TYPE OF DATA	SCHEDULE	LOCATION	TFC RQD	PARTICIPANTS: AMSAA	TECOM	OTEA	TRADOC	LEA	LOGC	BELVOIR	CRITERIA: MET	NOT MET
AISI	MARKET INVESTIGATION	MANPRINT: T-7, T-8, T-10, 0-4	FIELD 10 MISSIONS, ANALYSIS	OFF-THE-SHELF AISI	PERFORMANCE REPORTS	3QFY87	FT. BELVOIR, EPG					E,O	E		R,M		
"	"	DATA TRANSFER & REDUCTION: T-3, T-4, 0-2	"	MICRO-PROCESSOR, PRINTER, PLOTTER	"	"	DEFENSE MAPPING SCHOOL			E		E,O	E		R,M		
"	"	LOGISTICS: T-6, 0-5, 0-6, 0-7	FIELD OBSERVATION ANALYSIS	AISI, PROCESSOR PRINTER, PLOTTER	PERFORMANCE REPORTS, CONTRACTOR LITERATURE	4QFY87	FT. BELVOIR, EPG					E,O	E		R,M		

REMARKS

TFC KEY
C-CERTIFIER
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TEST KEY
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P-PARTICIPANT IN TEST
M-MONITOR TEST FOR EVALUATION
E-EVALUATION OF DATA ONLY
O-OBSERVE ONLY
BLANK-NONE

APPENDIX C - DISTRIBUTION LIST

AGENCY	CODE
Commander US Army Materiel Command Alexandria, VA	AMIDE-SS-V AMCQA-S AMCSM-WI AMCSM-WS AMCSM-SS
Headquarters, Department of the Army Washington, DC	DAEN-RDM
Commander US Army Armor Engineer Board Ft. Knox, KY 40121-5470	ATZA-AE ATZA-EN
Commander US Army Aviation Logistics School Ft. Eustis, VA 23604	ATSQ-CDM
Commander Material Readiness Support Activity Lexington, KY 45011	AMXMD-ED
Commander US Army Aberdeen Proving Ground Aberdeen, MD 21005-5055	STEAP-MT-U
Commander US Army Communication-Electronics Command Ft. Monmouth, NJ 07703	AMSEL-ME
Commander US Army Central Test Measurement and Diagnostic Equipment Activity Lexington, KY 40511	AMXCT-S
Commander US Army Combined Arms Center Ft. Leavensworth, KS	ATZL-TIEV
Commander US Army Logistics Evaluation Agency New Cumberland, PA 17070	DALO-LEI
Commander US Army Logistics Center Ft. Lee, VA 23801	ATCL-M ATCL-TEA ATCL-MSF ATCL-MS

TEST AND EVALUATION MASTER PLAN
(TEMP)

For The

AUTOMATIC INTEGRATED SURVEY INSTRUMENT
(AISI)

Departnent of the Army approved Required Opperational Capability (ROC) for an Army Topographic Support System (TSS); Approved 20 January 1976

DRAFT TEMP

TEMP PREPARED BY:

Directorate For Combat Engineering
Combat Construction Division
U.S. Army Belvoir Research, Development and Engineering Center
Fort Belvoir, VA 22060

(Revised 2 October 1987)

Release Limitations: Limited to U.S. Government Agencies Only

Security Classification: UNCLASSIFIED

TEMP CONCURRANCE RECORD

PRINCIPAL MEMBER	COMMANDER'S NAME OFFICE & AGENCY	REPRESENTATIVE SIGNATURE	DATE
MATERIEL DEVELOPER	U. S. Army Belvoir RD&E Center, STRBE-JCT		
TECHNICAL TESTER	U. S. Army Test and Evaluation Command, AMSTE-EV		
USER TESTER	U. S. Army Engineer Board, ATZK-AE-EN		
COMBAT DEVELOPER	U. S. Army Training and Doctrine Command, ATCD		
USER/ TRAINER	U. S. Army Engineer School ATZA-TE-TO		
OPERATIONAL EVALUATOR	U. S. Army Engineer School, ATZA-CDT		
TECHNICAL EVALUATOR	U. S. Army Test and Evaluation Command, AMSTE-EV		
LOGISTICIAN	U. S. Army Logistics Evaluation Agency, DALO-LEI		
OTHER			

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National Technical Systems

ENVIRONMENTAL TESTING
OF
AUTOMATED INTEGRATED SURVEY INSTRUMENTS (AISI'S)

National Technical Systems

Report No. 555-2134
P. O. No. 011553
Date 5 November 1987

ENVIRONMENTAL TESTING OF AUTOMATED INTEGRATED SURVEY INSTRUMENTS (AISI'S)

PREPARED FOR: RADIAN, Inc.
Huntwood Plaza
5845 Richmond Highway
Alexandria, VA 22303

PREPARED BY NATIONAL TECHNICAL SYSTEMS
D.C. Division
State Rout 748
Hartwood, VA 22471

National Technical Systems

Report No. 553-555
P. O. No. 011553
Date 5 November 1987

REVISION PAGE

Rev. No.	Date	Page No.	Para. No.	Description
Original	5 November 1987	-	-	-

National Technical Systems

Report No. 55-2134
P. O. No. 011553
Date 5 November 1987

SIGNATURES

Written by Peter W Pettoni Date 9 November 1987
Peter W. Pettoni, Technical Writer

Approved by William J. Ison Date 11-9-87
William J. Ison, Environmental Laboratory Manager

Reviewed by Peter W. Pettoni Date 9 November 1987
Peter W. Pettoni, Quality Control Manager

TABLE OF CONTENTS

Report No. 555-2134
P. O. No. 011553
Date 5 November 1987

1.0 PURPOSE

1.1 The purpose of this report is to present the test procedures used and the results obtained during the performance of an environmental test program conducted to determine the conformance of automated Integrated Survey Instruements (AISI's) to the requirements specified in the references in paragraph 2.0.

2.0 REFERENCES

2.1 Radian, Inc. Purchase Order Numbers 011553 and 01937.

2.2 Operational/Environmental/Suitability Test Plan for Automated Integrated Surveying Instrument (AISI).

3.0 TEST ITEMS

One (1) Geodimeter, System 440 S/N 69417, and one (1) Theodolite, Wild T-2000, S/N FNR 314109, both with accessory equipment, were received for testing.

4.0 SUMMARY

The Geodimeter and Wild were subjected to environmental testing in accordance with the requirements of the references in paragraph 2.0.

Out-of-case vibration testing was halted on both test items at the request of the Radian representative. Refer to the Notice of Deviation Number 1 in Appendix C.

After In Transport Case Shock testing, it was noted that the head aligning dowels and slots of the Wild T-2000 were badly worn.

There was no other damage noted to either test item as a result of testing.

Refer to NTS/Action Test Report 23805-88M (included herein) for results of EMI and Magnetic Environment Testing.

5.0 TEST CONDITIONS AND TEST EQUIPMENT

5.1 Test Conditions

Unless otherwise specified herein, testing was performed at room ambient conditions defined as a temperature of 73 ±18°F (23 ±10°C), a relative humidity of 50 +40, - 30 percent, and a barometric pressure of 28.5 +2.0, -3.0 inches of mercury absolute (725 +50, -75 mm Hg).

5.2 Test Equipment

An itemized list of the test equipment used is included in Appendix A of this report. This equipment is calibrated, as required, in accordance with MIL-S-45662 with Change Notice 1, and calibration is traceable to the National Bureau of Standards. Calibration records are maintained on file at NTS/Hartwood.

6.0 TEST DESCRIPTION AND RESULTS

6.1 High-Temperature Operation

The AISI test items were subjected to High-Temperature Operation testing in accordance with Procedure Index VII at reference 2.2.

The AISI items, in operational configuration, and including all accessories and cases, were concurrently placed in an environmental chamber at ambient temperature. The chamber internal temperature was then raised to 122°F (50°C) in 2 hours, and the test items were then soaked for 4 hours. After the 4-hour soak at 122°F (50°C), the chamber internal temperature was reduced in 2 hours to 68°F (20°C).

The steps described above were then repeated three (3) additional times, for a total of 4 high-temperature cycles. At the completion of the fourth high-temperature cycle, the Radian representative performed functional tests of AISI items, and the items were visually examined.

Results - High-Temperature ~~Storage~~

There was no visual damage noted to the AISI items as a result of testing.

The Radian representative recorded and retained results of the functional test.

Refer to Appendices B and D for temperature plots and photographs of the test setup.

6.2 High-Temperature Storage

The AISI test items were subjected to High-Temperature Storage testing in accordance with Index VIII of reference 2.2.

The nonoperating test items were placed in a chamber at ambient temperature. The chamber internal temperature was then raised in 2 hours and 10 minutes to 71°C (160°F), and the AISI items were soaked for 4 hours. The chamber temperature was then reduced to ambient in 2 hours. The test items were then stored at ambient for 13 hours and 40 minutes, after which the test items were removed and subjected to functional checks and visual examination.

NOTE: The batteries were not in place in the test items during this test.

Results - High-Temperature Storage

There was no visual damage noted to the test items.

The Radian representative recorded and retained the results of functional tests.

Refer to Appendix B for recorded temperature plots, and Appendix D for photographs.

6.3 Low-Temperature Storage

The test items were subjected to Low-Temperature Storage testing in accordance with Index XV of reference 2.2.

The test items (with batteries installed) were placed into a chamber at ambient temperature. The internal chamber temperature was then decreased in 5 hours to -50°F (-45.6°C), and the units were soaked for 6 hours. The chamber internal temperature was then increased in 4-1/2 hours to 86°F (+30°C), and the test items were dried out for 32 hours. At the completion of the 86°F (+30°C) 32-hour drying-out period, the internal chamber temperature was returned to ambient, and the test items were removed and subjected to visual examination and functional checks by the Radian representative.

Results - Low-Temperature Storage

There was no visual damage noted to the test items.

The Radian representative recorded and retained results of the functional tests.

Refer to Appendix B for plots of chamber temperature, and Appendix D for photographs.

6.4 Low-Temperature Operation

The AISI items were subjected to Low-Temperature Operation testing in accordance with reference 2.2.

The AISI test items (with batteries installed), with open cases, and other accessories, were placed into a chamber at ambient temperature. The chamber temperature was then lowered to -5°F (-20.6°C) in 2 hours and 50 minutes, and the test items were soaked for 4 hours and 5 minutes. At the end of the 4-hour and 5-minute soak, the Radian representative performed functional tests of the test items, and the items were visually examined.

Results - Low-Temperature Operation

The Radian representative recorded and retained results of the functional tests.

There was no visual damage noted to the test items.

Refer to Appendix B for temperature plots, and Appendix D for photographs of the test setup.

6.5 Humidity

The AISI test items were subjected to Humidity testing in accordance with Index XIII of reference 2.2.

The test items (with batteries installed), with open cases, and all accessories open, were placed into a chamber at ambient conditions. The chamber temperature and relative humidity (r.h.) were increased to 120°F (48.9°C) and 95% in 1 hour and 35 minutes, and the test items were soaked at these conditions for 24 hours. After 24 hours at 120°F and 95% r.h., the chamber conditions were returned to ambient in 35 minutes, and the test items were allowed to stabilize for 4 hours. At the end of the 4-hour stabilization period, the Radian representative performed functional tests of the items, and the items were visually examined.

Results - Humidity

There was no visual damage noted to the test items.

The Radian representative recorded and retained results of the functional tests.

Refer to Appendices B and D for traces of the chamber temperatures and test setup photographs.

6.6 Sand and Dust

The AISI test items were subjected to Sand and Dust testing in accordance with Index XXX of reference 2.2.

The two test items (out of case and without lens covers), and the transport cases (closed) were placed into the sand and dust chamber.

The chamber temperature was increased to 23°C with the relative humidity maintained at less than 25% and the air velocity maintained at 240 feet per minute. Once these conditions were obtained, the dust feeder was turned on, blowing dust onto the test items at a rate of 0.3 ±0.2 grams per cubic foot. These conditions were maintained for 15 minutes. All chamber controls were then turned off, and the test items were allowed to return to ambient conditions. The accumulated dust was brushed off and the test items were then visually examined.

Results - Sand and Dust

There was no visual damage noted to the tested items.

Refer to Appendix D for photographs of the setup.

6.7 Rain

The AISI test items were subjected to Rain testing in accordance with Index XVII of reference 2.2.

The two test items, in operating positions, were placed into a chamber preconditioned to 68°F (20°C) and soaked for 30 minutes. The items were then removed from the chamber and placed in the rain test setup.

The rain test was begun by exposing one side of the items to 5 minutes of wind-driven rain at a rainfall rate of 3 inches/hour, with no rain cover on the items. The rainfall was then stopped, and rain covers were installed. The rainfall was then restarted and continued for 10 minutes. The remaining three sides were then consecutively exposed to 15 minutes of rainfall each. After rain exposure to all four sides, the items were wiped down, the covers (as applicable) were removed, and the items were visually examined and subjected to functional tests.

Results - Rain

Water, 1/8-inch deep was found inside the case of the Wild T-2000. The Wild T-2000 also had water inside its bottom lens.

The Radian representative recorded and retained results of functional tests.

Refer to Appendices B and D for temperature plots and photographs of the test setup.

6.8 Vibration, Out-of-Case

The AISI items were subjected to Out-of-Case vibration testing in accordance with Index XIX of reference 2.2.

The AISI items were rigidly secured separately to an electrodynamic vibration exciter and exposed to sinusoidal vibration cycling in the X-axes at the following levels and frequencies:

10-55 Hz @ 0.10 in. DA
15 cycles (10-55-10 Hz) at 15 minutes/cycle

Results - Vibration, Out-of-Case

During the X-axis vibration of both test items, testing was stopped as noted below at the request of the Radian representative, who judged that the testing was excessive.

T-2000, X-axis, @ 38.7 Hz
Geodimeter, 440 X-axis, @ 21 Hz

Refer to Appendix C, Notice of Deviation, and Appendices B and D for vibration plots and photographs of the test setup.

6.9 Vibration, In Transport Case

The AISI items were subjected to Vibration (In Transport Case) testing in accordance with Index XX of reference 2.2.

The test items were rigidly secured (separately) to an electrodynamic vibration exciter and exposed to vibrational cycling in each of three mutually perpendicular axes at the following frequencies and levels.

7-200 @ 1.5 g's peak
One cycle (7-200-7 Hz @ 5 minutes/cycle) per axis

At the completion of each vibration cycle, the items were visually examined and subjected to functional testing by the Radian representative.

Results - Vibration (In Transport Case)

There was no visual damage noted in either test item.

The Radian representative recorded and retained results from functional testing of the items.

Refer to Appendices B and D for vibration plots and photographs of the test setup.

6.10 Solar Radiation

The AISA items were subjected to Solar Radiation testing in accordance with Index X of reference 2.2.

The AISA items were placed in an environmental chamber. A source of simulated solar radiation of 345 BTUs/ft^2 was directed to the items for 4 hours. At the end of the 4-hour period of 345 BTU/ft^2 simulated solar radiation, the test items were removed and subjected to visual examination, then to performance test by the Radian representative.

Results - Solar Radiation

There was no visual damage noted to the test items.

The Radian representative recorded and retained results of the performance tests.

Refer to Appendices B and D for chamber temperature plots and photographs of the test setup.

6.11 Shock, In Transport Case

The AISI items were subjected to Shock testing in accordance with Index XXI of reference 2.2.

Each AISI test item, installed in its respective transport case, was subjected to Shock testing so that each of the six case faces was "flat-dropped", and such that four corners (two by the top shell, and two by the bottom shell) of each case were dropped from a height of 42 inches (10 drops/case total). The cases and AISI items were then subjected to visual examination, and performance tests.

Results - Shock, In Transport Case

There was no visual damage noted to the cases.

The head aligning dowels and slots of the Wild T-2000 were badly worn.

The Radian representative indicated that the T-2000 unit was out of alignment. The Radian representative aligned the unit, then performed performance tests on both AISI items, and recorded and retained results of the tests.

Refer to Appendices B and D for vibration plots and photographs of the test setup.

APPENDIX A
Test Equipment List

NTS National Technical Systems

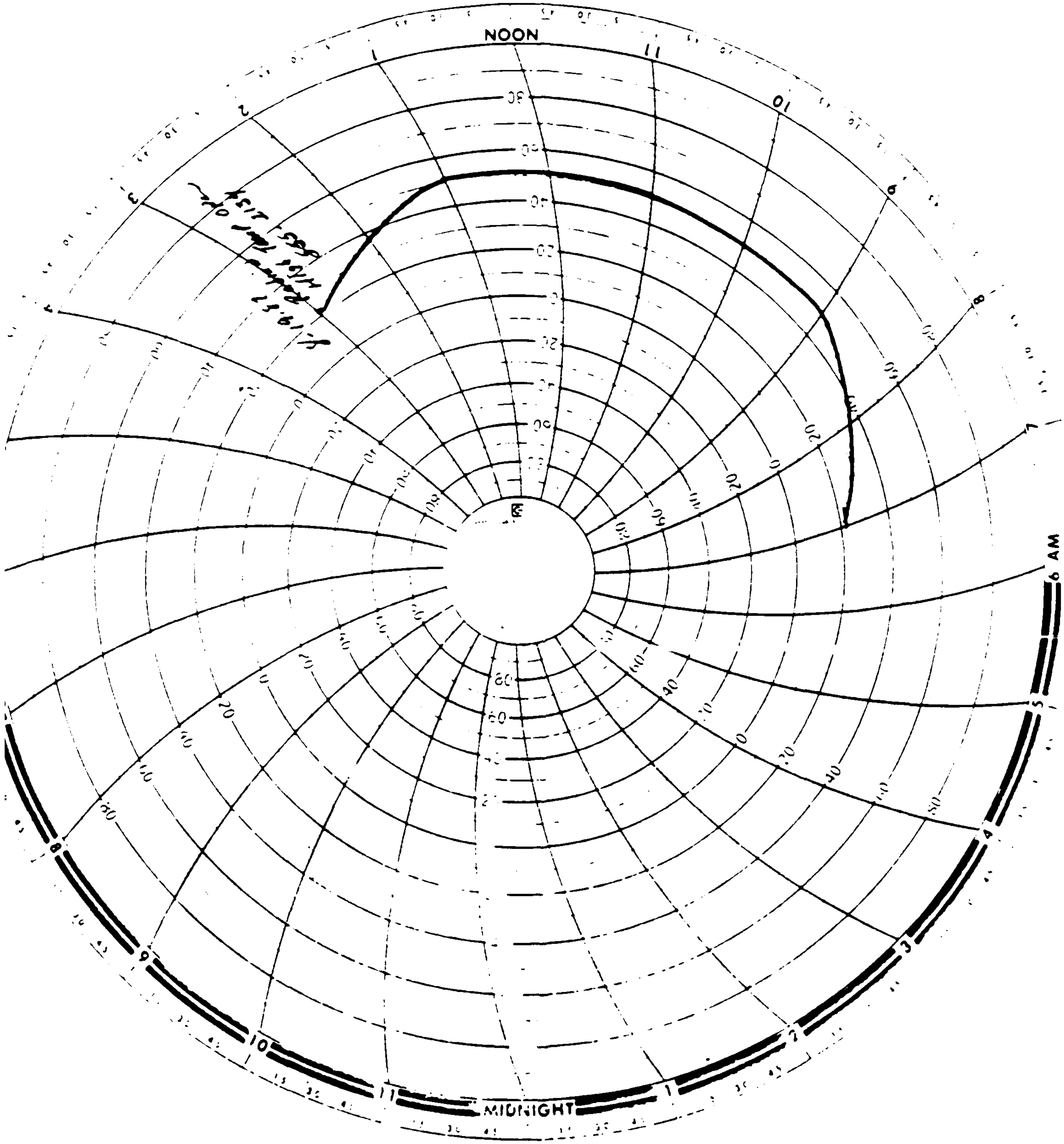
Report No. 553-2134
P. O. No. 011553
Date 5 November 1987

TEST EQUIPMENT LIST

	Instrument	Manufacturer	NTS Id No.	Cal. Date	Cal. Due
High and Low Temperature Tests					
	Chamber	Standard	ENV 6301 D	Used with calibrated equipment	
	Recorder	Honeywell	ENV 6005 D	7-28-87	1-28-88
Humidity					
	Chamber	Standard	ENV 6303 D	Used with calibrated equipment	
	Recorder	Honeywell	ENV 6047 D	4-20-87	10-20-87
Sand and Dust					
	Recorder	Leeds & Northrop	E 6034 D	4-15-87	10-15-87
	Anemometer	Airflow	ENV 6053 D	8-6-87	8-6-88
	Scale	Mettler	G 6000 D	2-13-87	8-13-87
Rain					
	Rain Gage	Springfield	ENV 6039 D	2-14-87	2-14-88
	Anemometer	Airflow	ENV 6053 D	8-6-87	8-6-88
	Chamber	Standard	ENV 6301 D	Used with calibrated equipment	
	Controller	Honeywell	ENV 6005 D	7-28-87	1-28-88
Vibration					
	Vibration Exciter	MB Electronics	D 6303 D	Used with calibrated equipment	
	Vibration Controller	Hewlett-Packard	D 6127 D	6-8-87	6-8-88
	Signal Conditioner	PCB	D 6092 D	7-13-87	1-13-88
	Accelerometer	PCB	D 6051 D	7-6-87	1-6-88
	Accelerometer	PCB	D 6050 D	7-7-87	1-7-88
Shock					
Solar Radiation					
	Pyranometer	Eppley	G 6022 D	9-6-85	9-25-87
	Chamber	Standard	ENV 6322 D	Used with calibrated equipment	
	Recorder	Honeywell	ENV 6005 D	7-28-87	1-28-88

APPENDIX B

Temperature and Vibratio n Plots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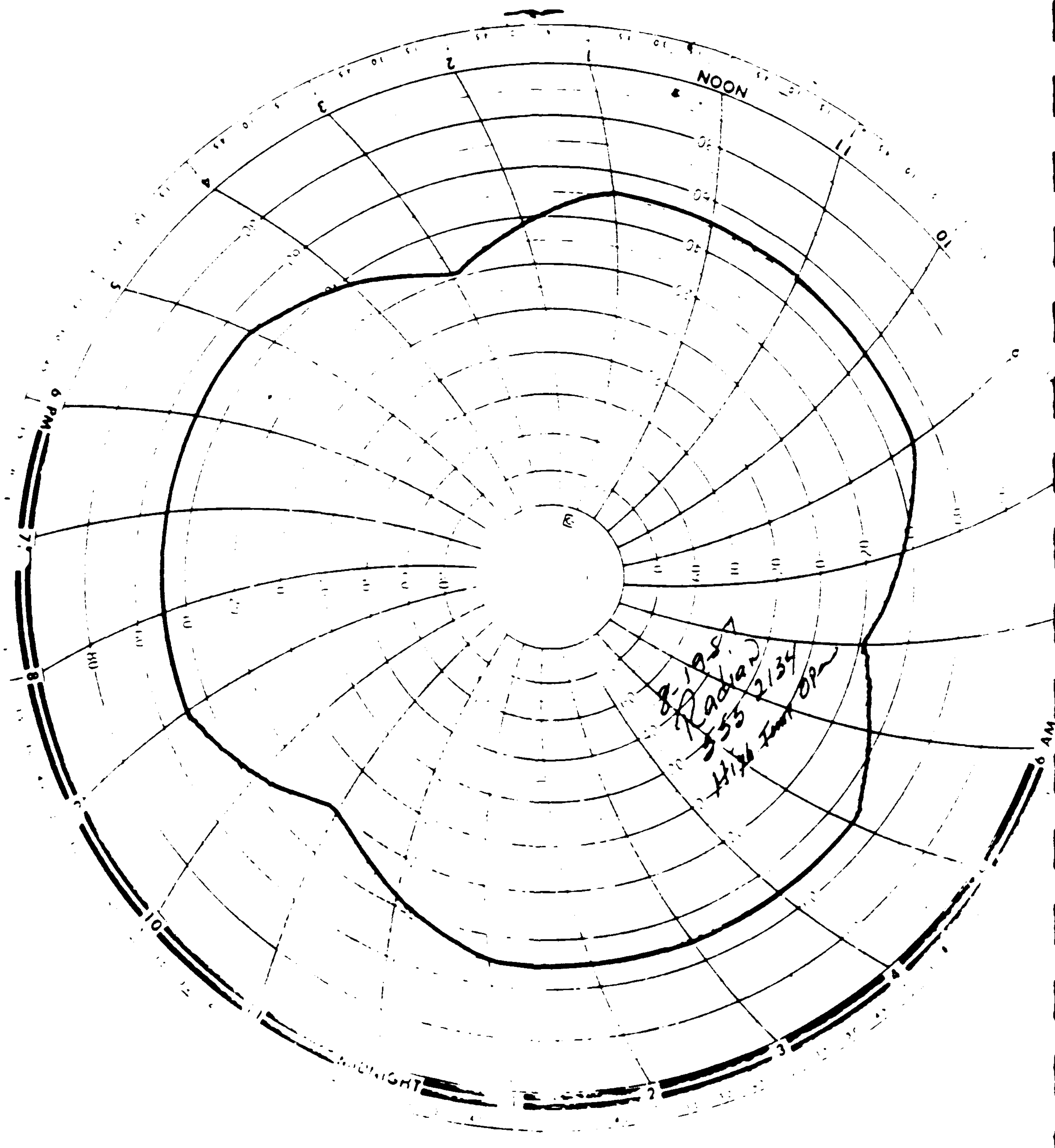
6 AM
MIDNIGHT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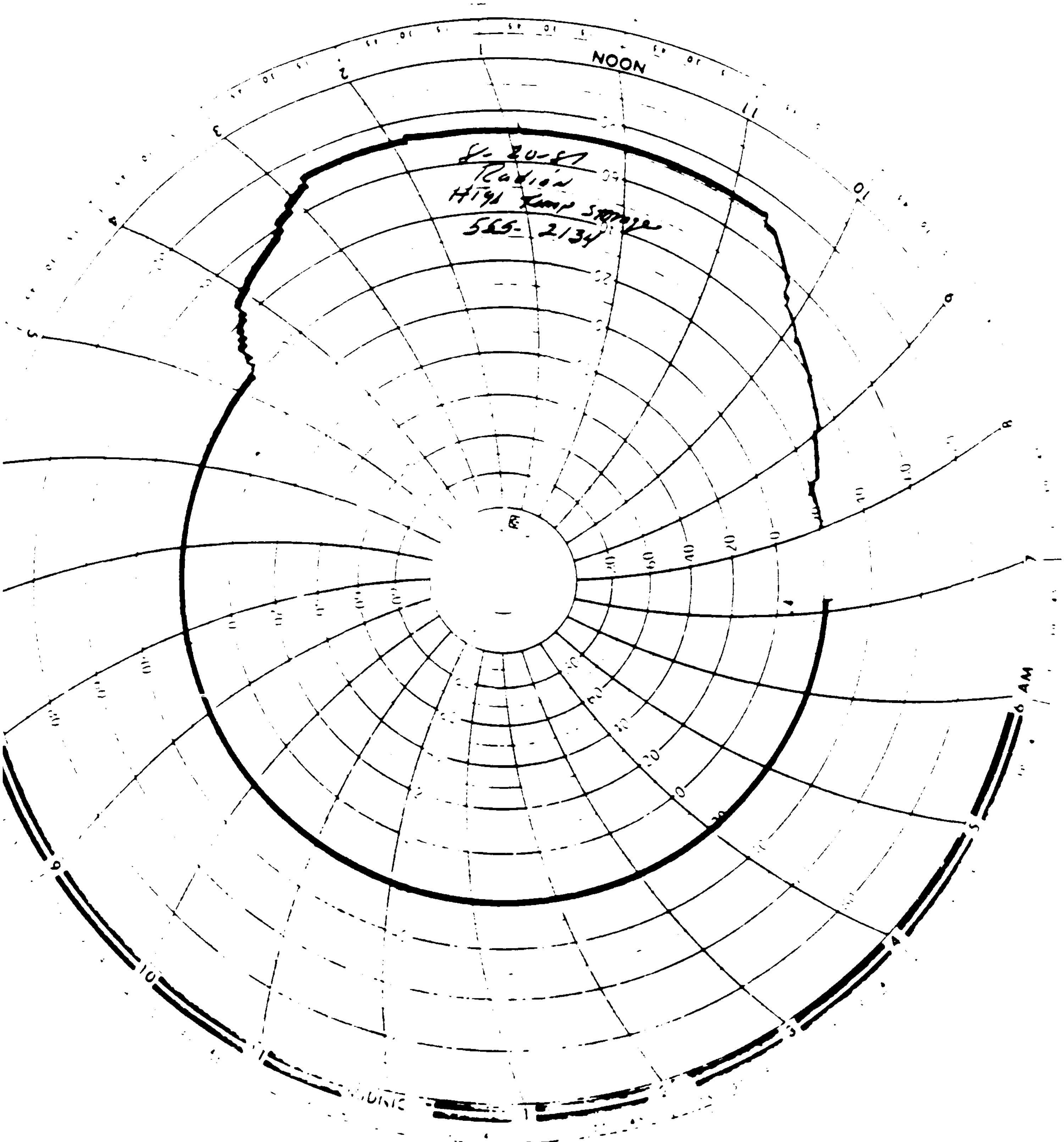
6 AM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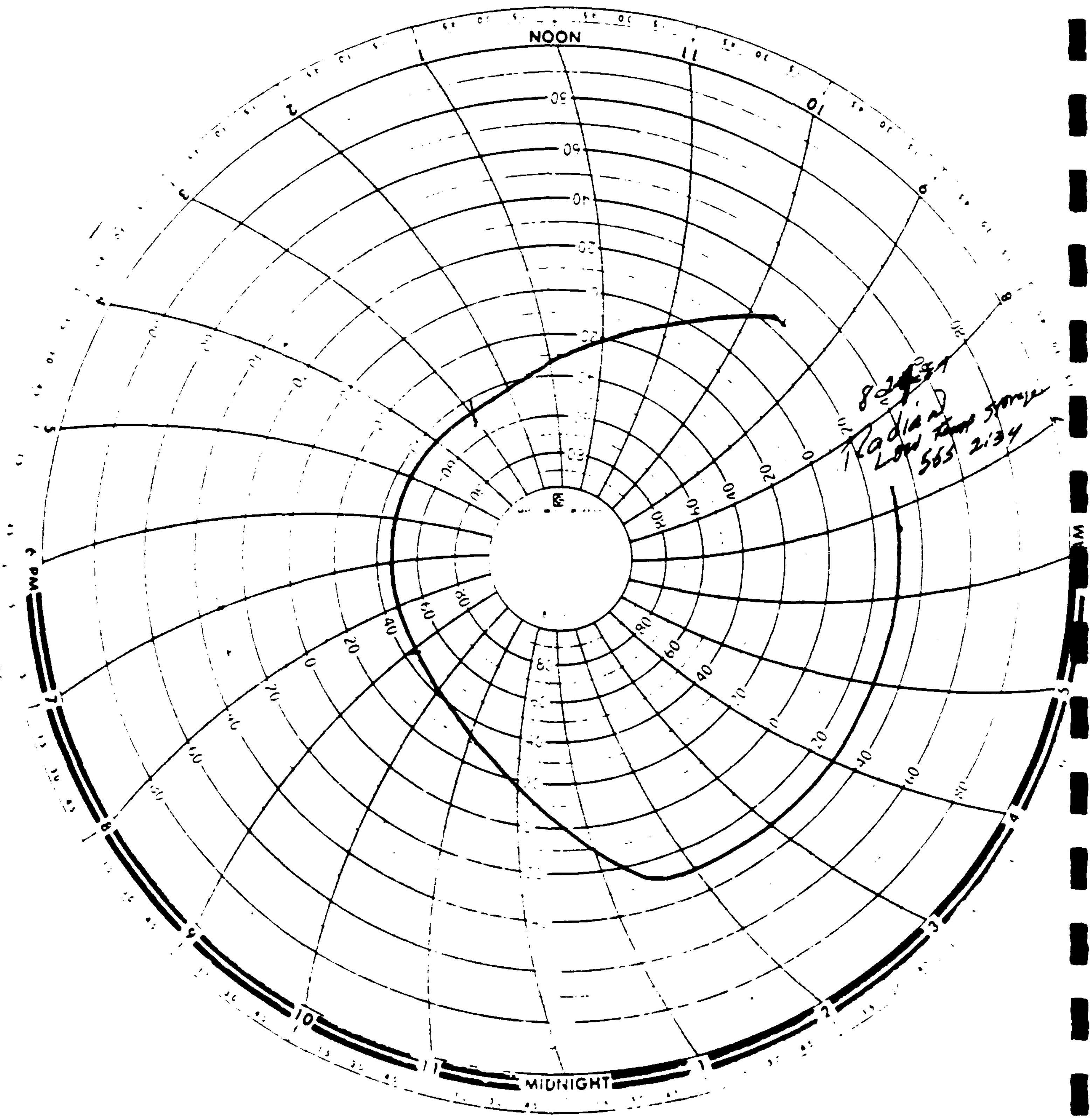
8-20-87
Radian
High Temp storage
565-2134
6 AM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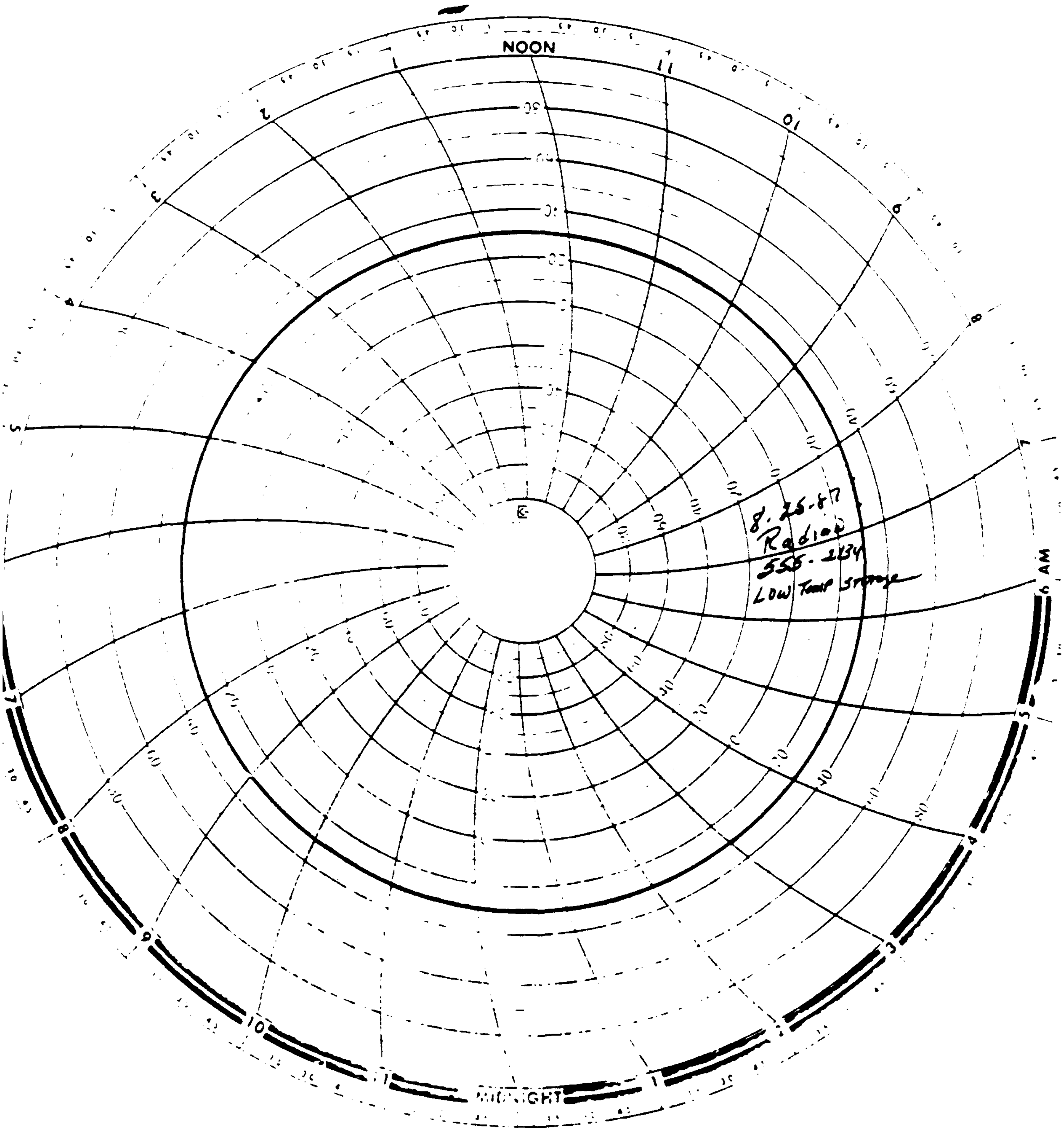
MIDNIGHT
PM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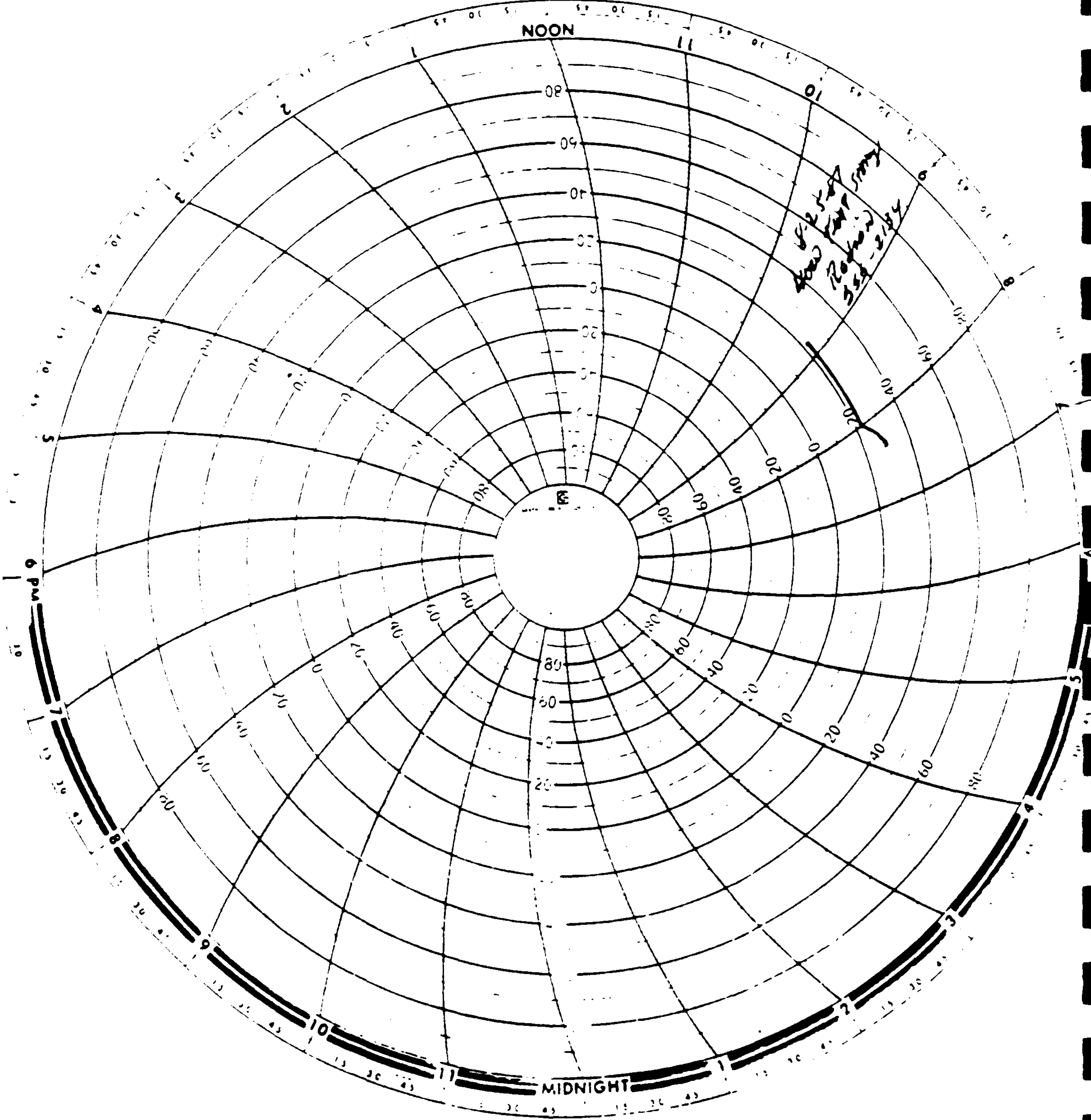
AM
8-25-87
Radio
555-2134
LOW Temp storage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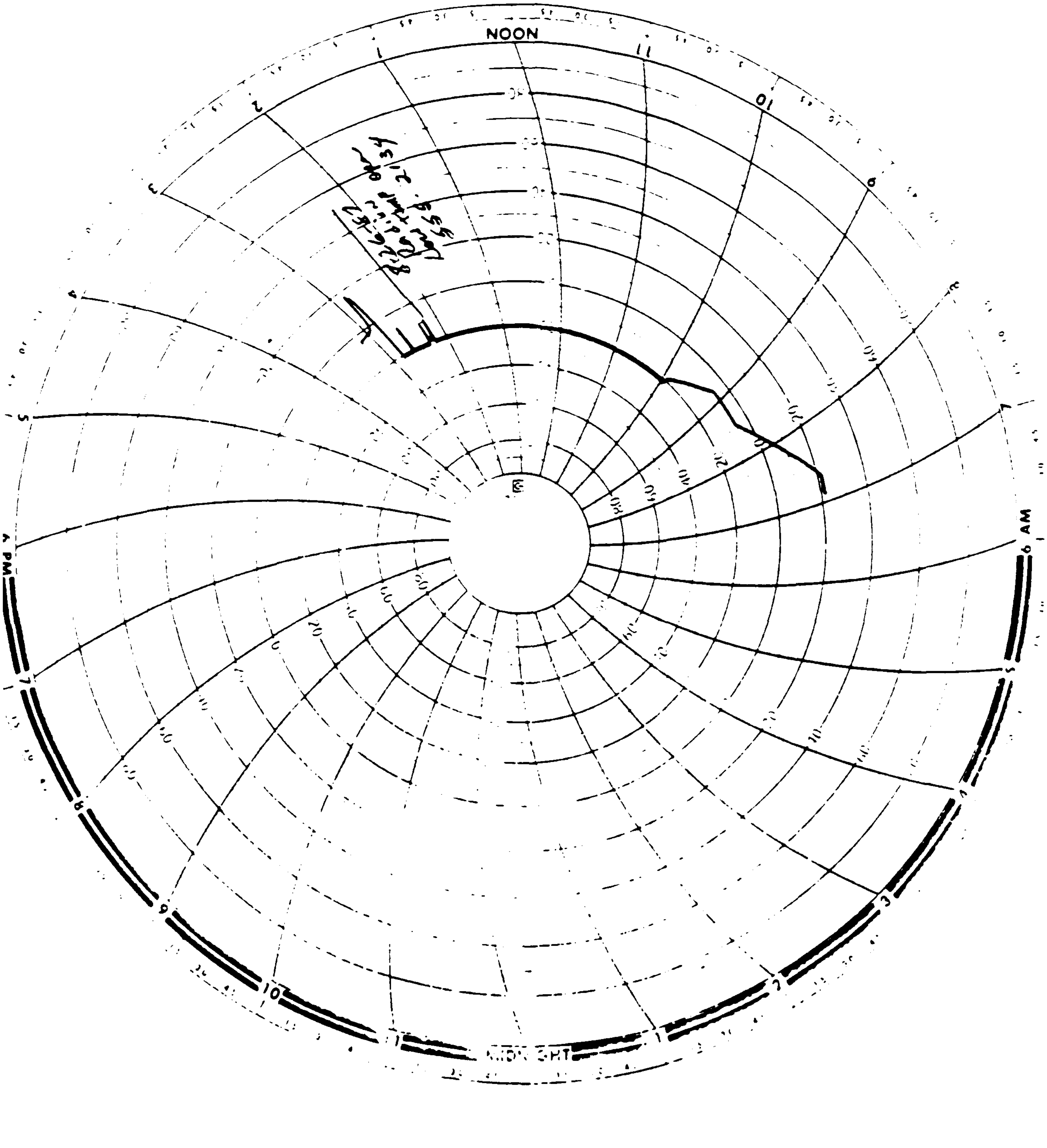
6 PM
MIDNIGHT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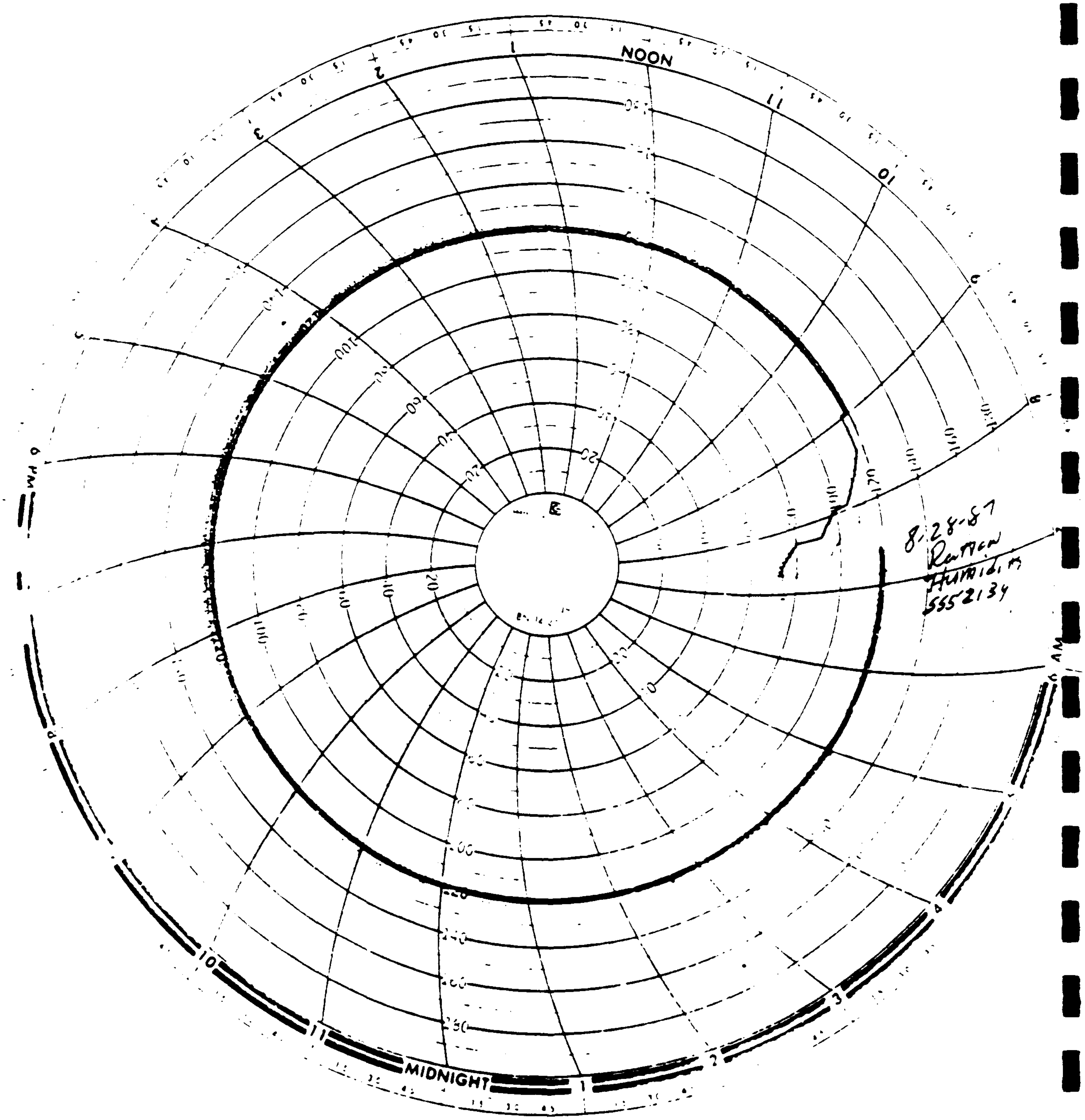
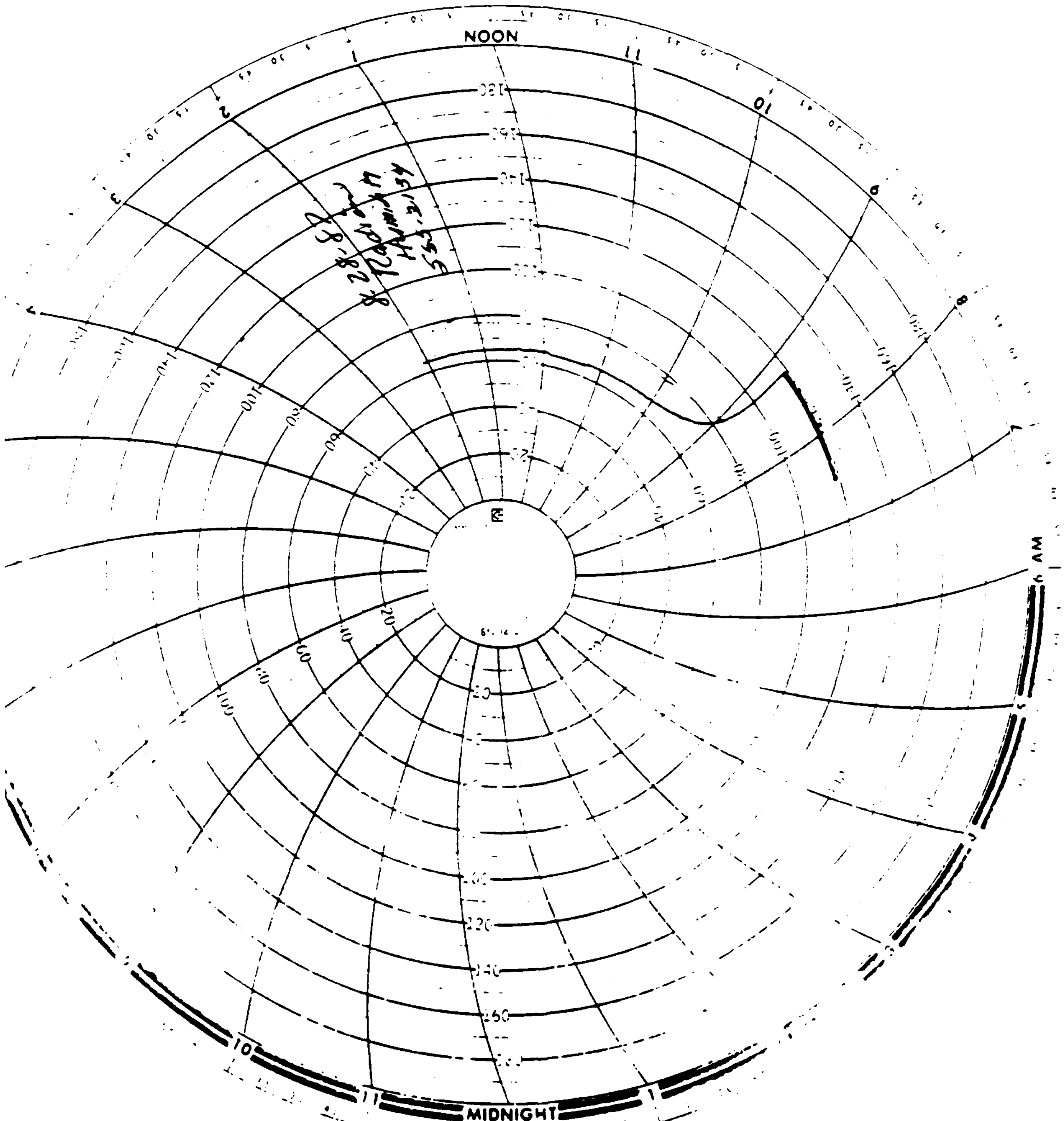
6 PM



NOON
MIDNIGHT
PM
AM
8-28-87
Reutten
Humidity
5552134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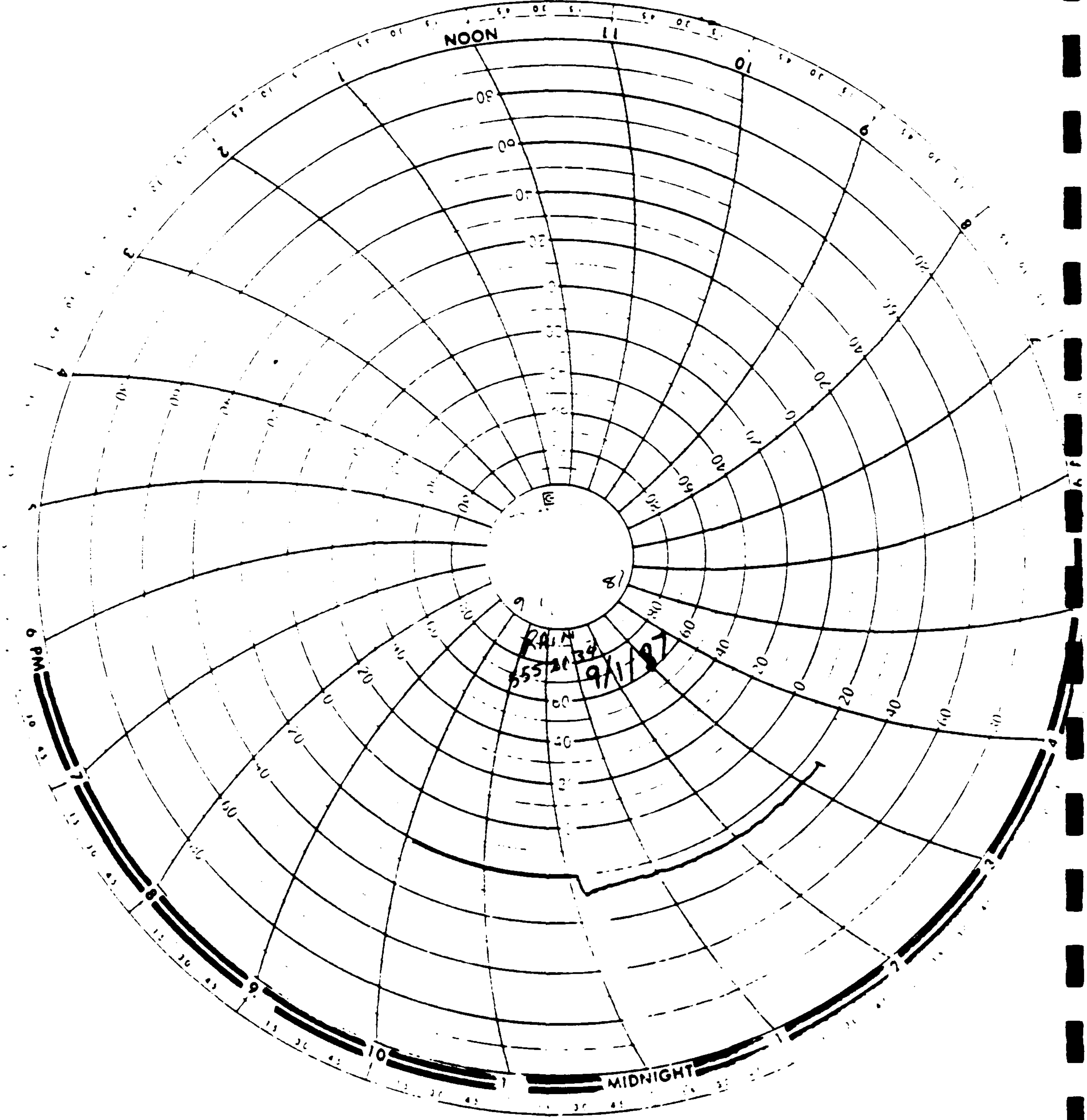
MIDNIGHT
AM


NOON
MIDNIGHT
6 PM
RAIN
9/1/87

APPENDIX C
Notice of Deviation

NTS

NOTICE OF DEVIATION

CUSTOMER Radian, Inc

MJO NO 555-2134

PART NAME Geodimeter / Wild

P.O NO 011553

PART NO T2000 / 4410

NOD NO 1

SERIAL NO. ERN-31419 / 69417

DATE 9-4-87

TEST SPECIFICATION MIL-S-53046

REV. —

PARA NO 4.5.2.11

TEST TITLE Vibration out of Case

ORIGINATOR E Poren

REQUIREMENT: Performance of Out of Case Vibration

DEVIATION: Test item response to vibration exposure was judged as severe and damaging

DISPOSITION: Testing stopped @ Customer request
Abort one sweep up first axis @ 38.7 Hz on Wild T-2000
Abort one sweepup first axis @ 21 Hz on Geodimeter 4410

REVIEW: (NTS QC)

APPROVAL: (Customer Representative)

CUSTOMER NOTIFICATION:

Made to: Radian, Inc Representative

How: Verbal

Date & Time 9-4-87 @ 1400

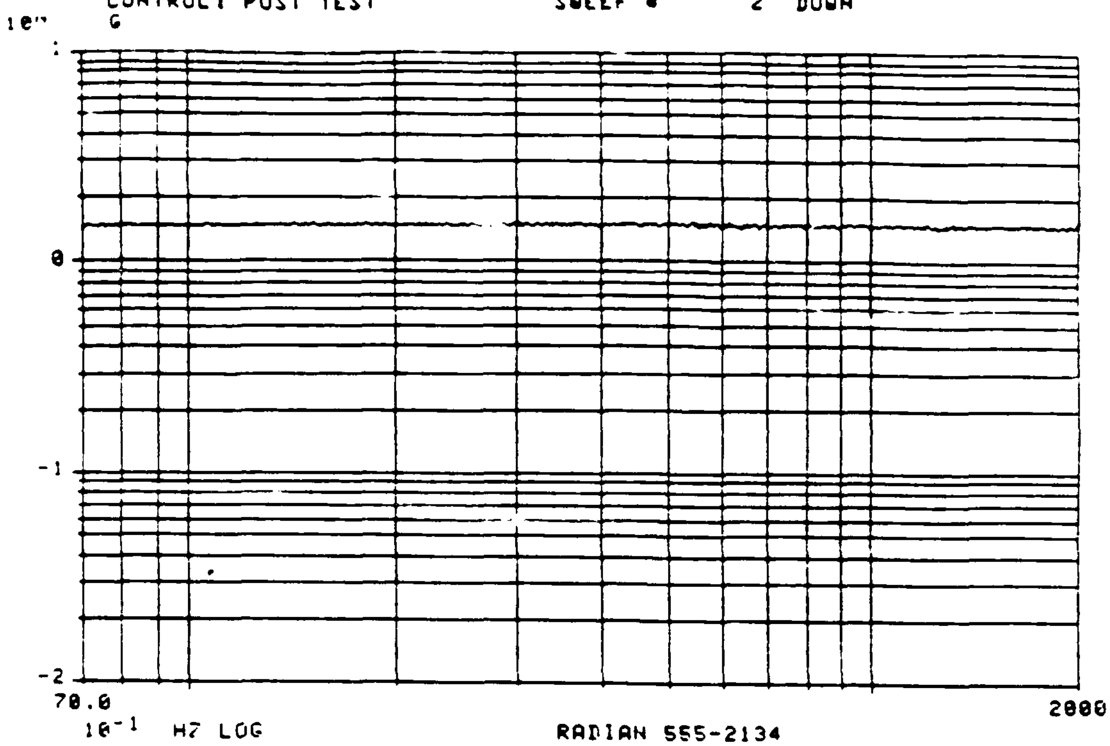
By: W. J. [signature]

DCAS Notified Yes ☐ N/A ☐ N/A DATE

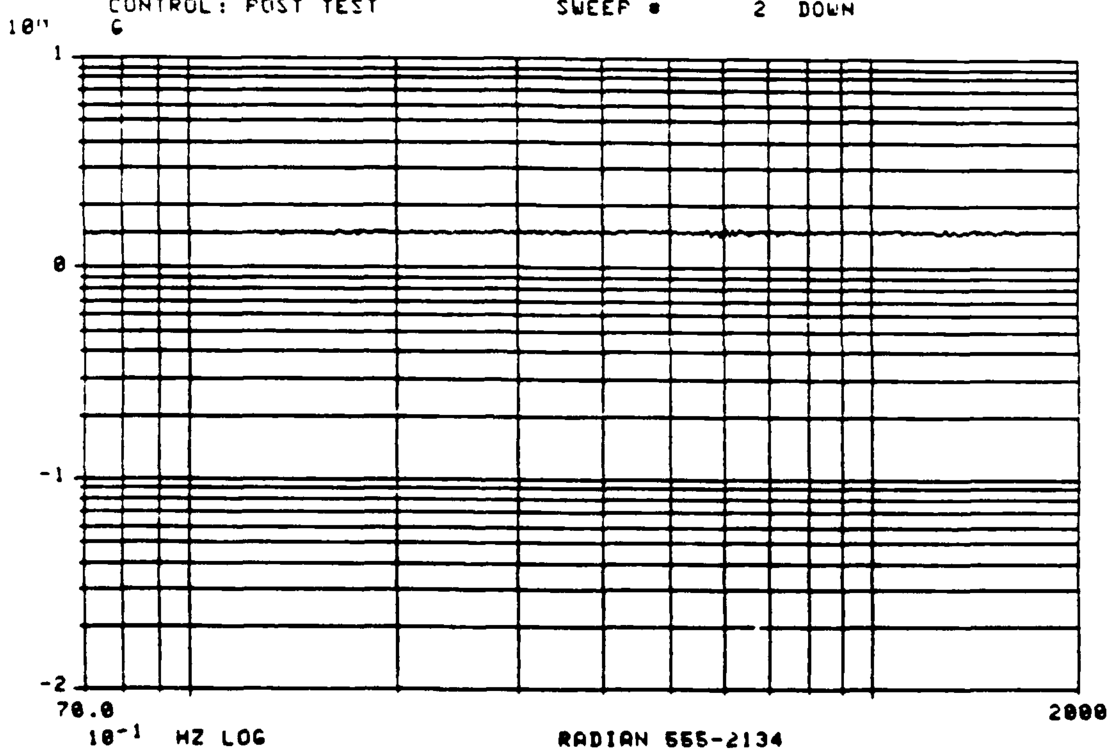
NTS Dept Supervisor

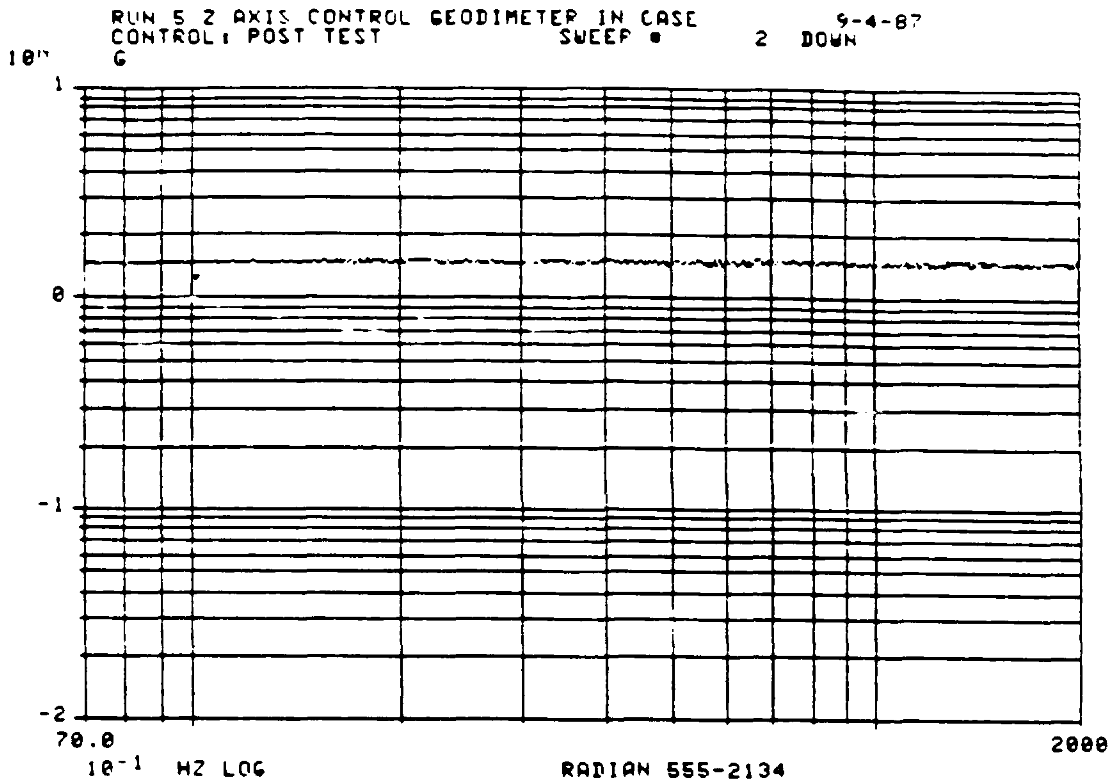
3

RUN 3 X-AXIS CONTROL GEODIMETER IN CASE 9-4-87
CONTROL: POST TEST SWEEP # 2 DOWN



RUN 4 Y-AXIS CONTROL GEODIMETER IN CASE 9-4-87
CONTROL: POST TEST SWEEP # 2 DOWN




RUN 5 Z AXIS CONTROL GEODIMETER IN CASE 9-4-87
CONTROL: POST TEST SWEEP # 2 DOWN
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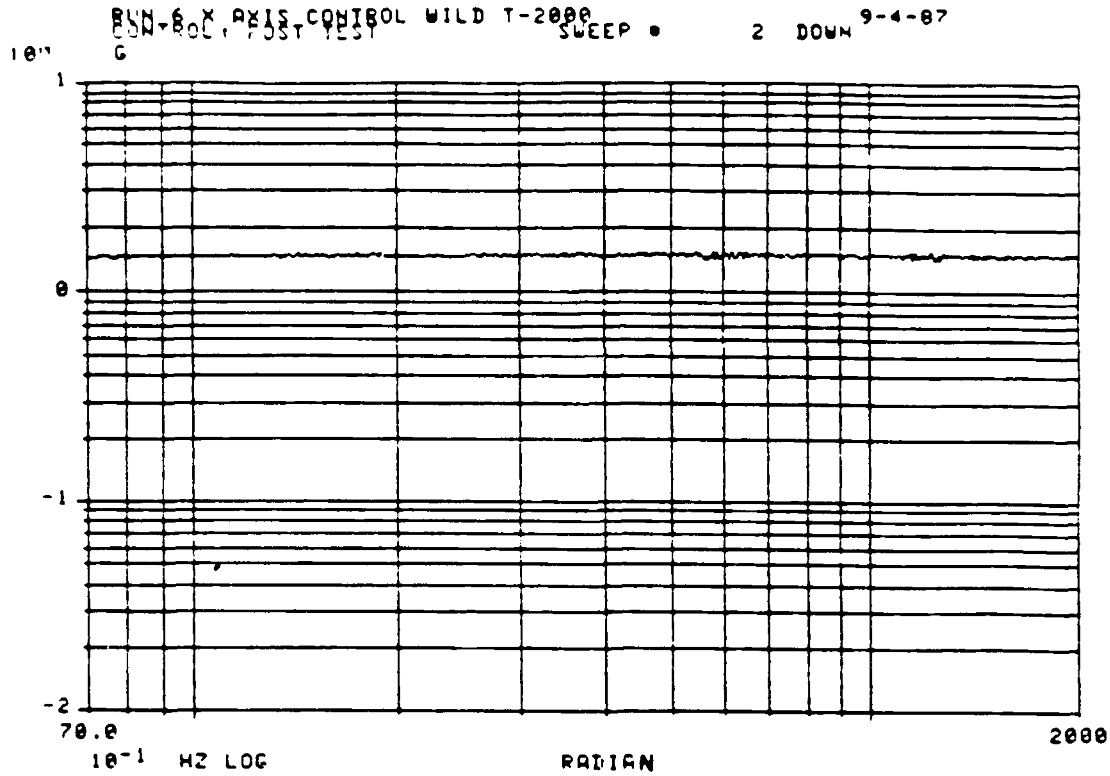
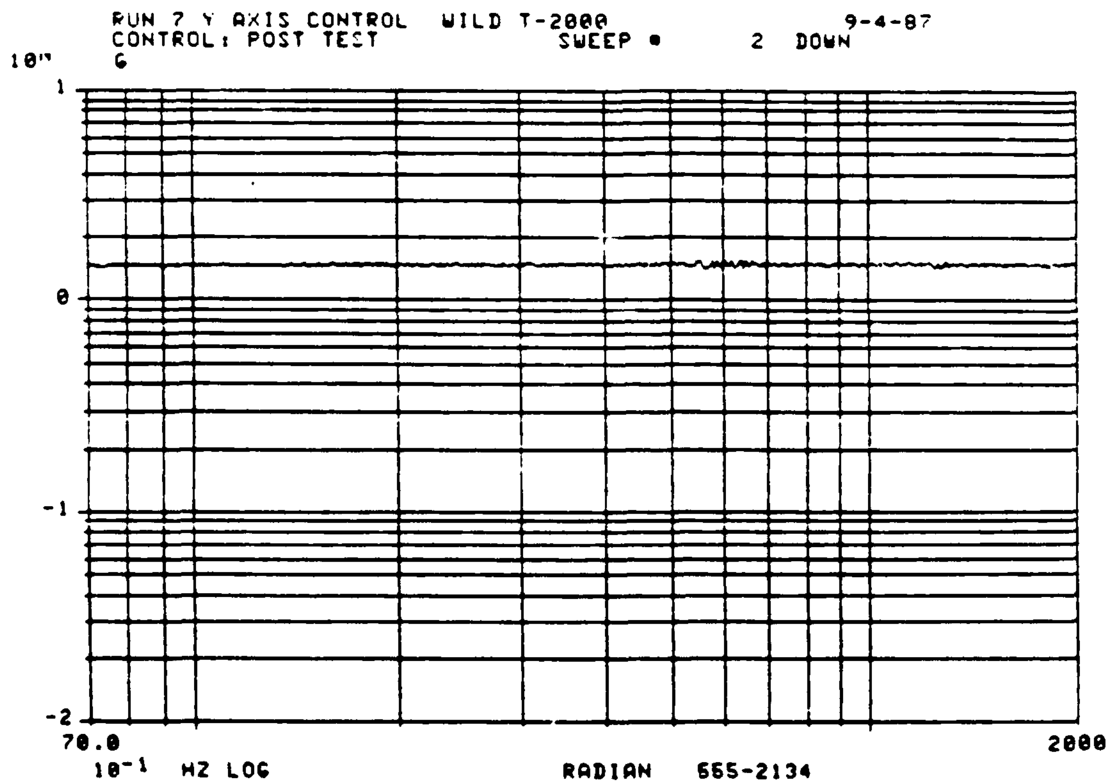
0
-1
-2
70.0
2000
10^-1 HZ LOG
RADIAN 555-2134


RUN 6 X AXIS CONTROL WILD T-2000
CONTROL: POST TEST
SWEEP ● 2 DOWN
9-4-87
10"
G
1
0
-1
-2
70.0
2000
10⁻¹ HZ LOG
RADIAN


RUN 7 Y AXIS CONTROL WILD T-2000
CONTROL: POST TEST
SWEEP ● 2 DOWN
9-4-87
10"
G
1
0
-1
-2
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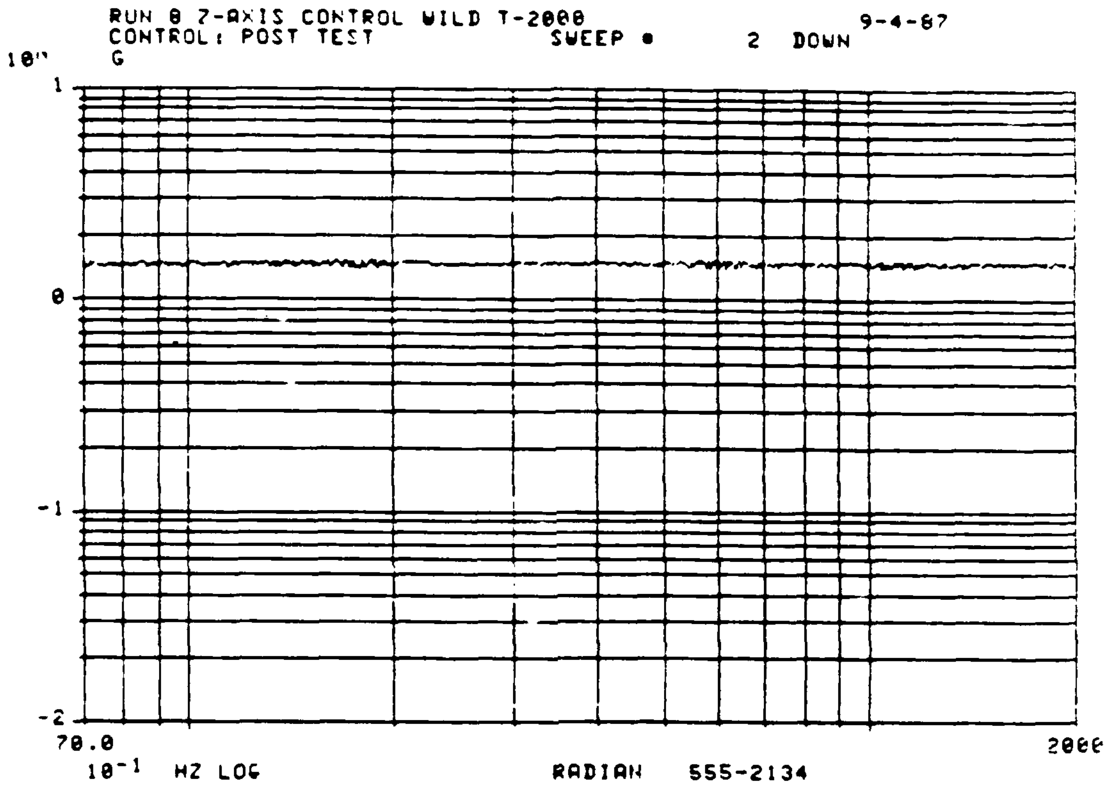
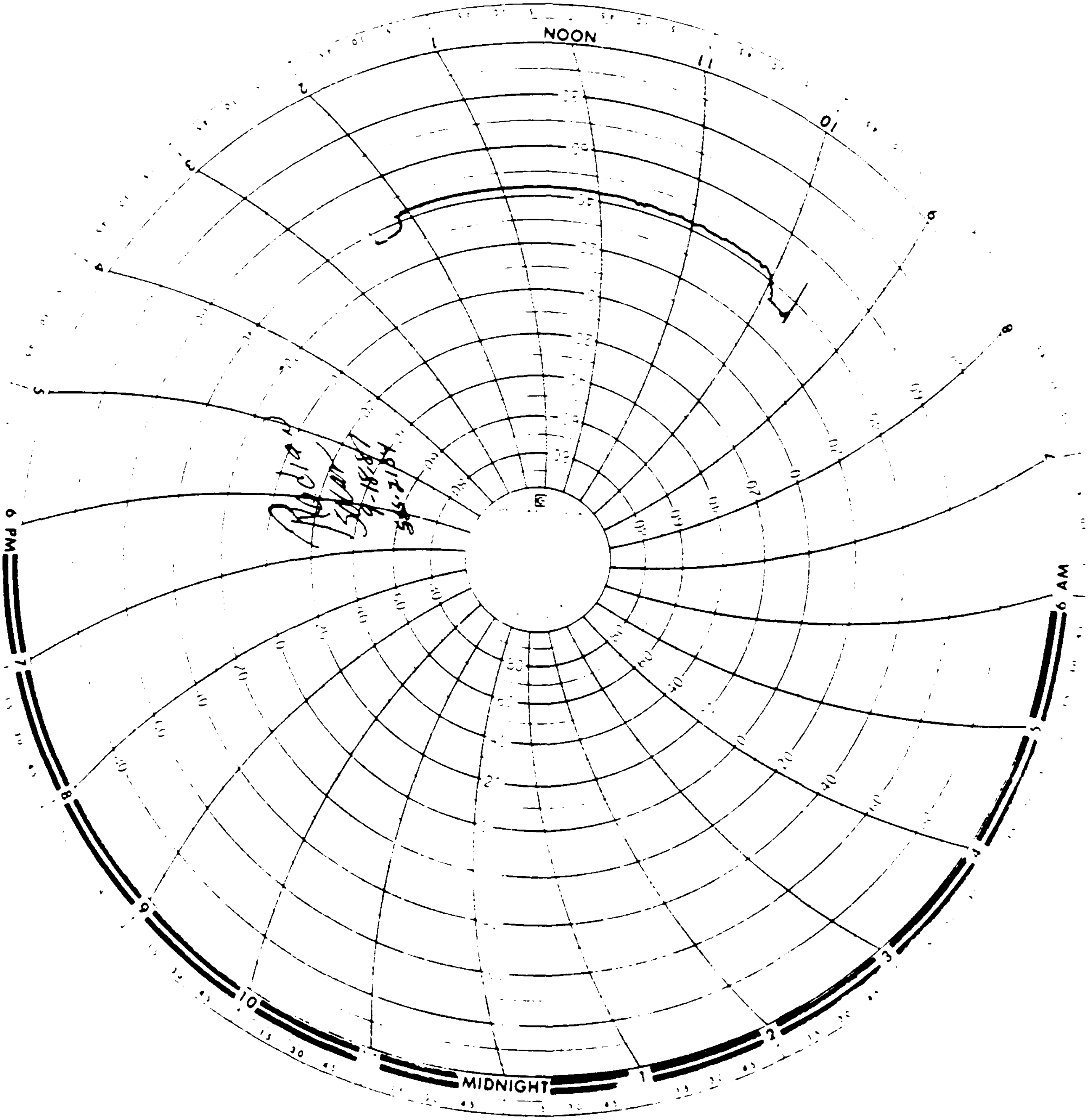
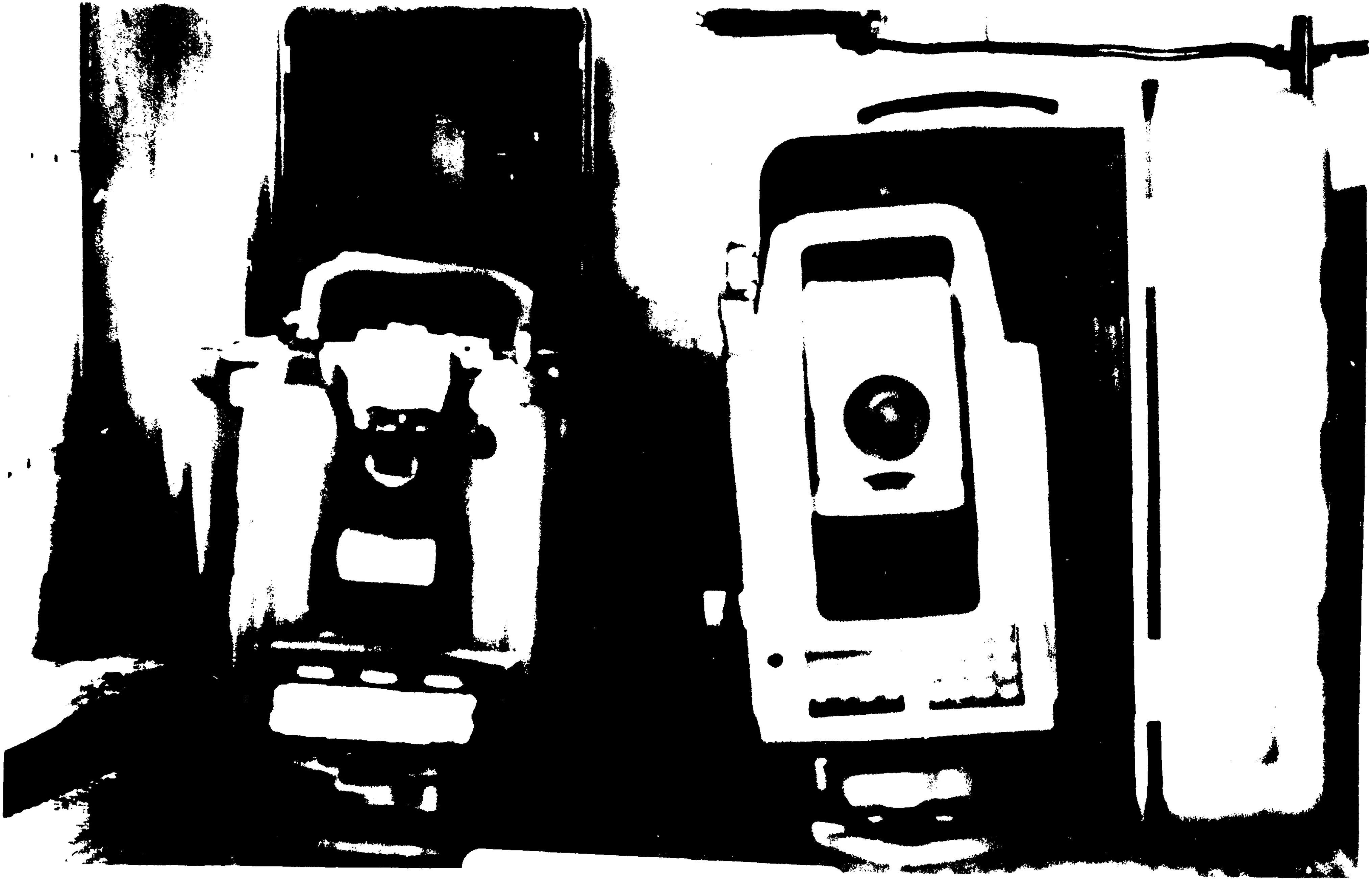
10⁻¹ HZ LOG
RADIAN 555-2134


RUN 8 Z-AXIS CONTROL WILD T-2000
CONTROL: POST TEST
SWEEP # 2 DOWN
9-4-87
10" G
1
0
-1
-2
70.0
2000
10^-1 HZ LOG
RADIAN 555-2134

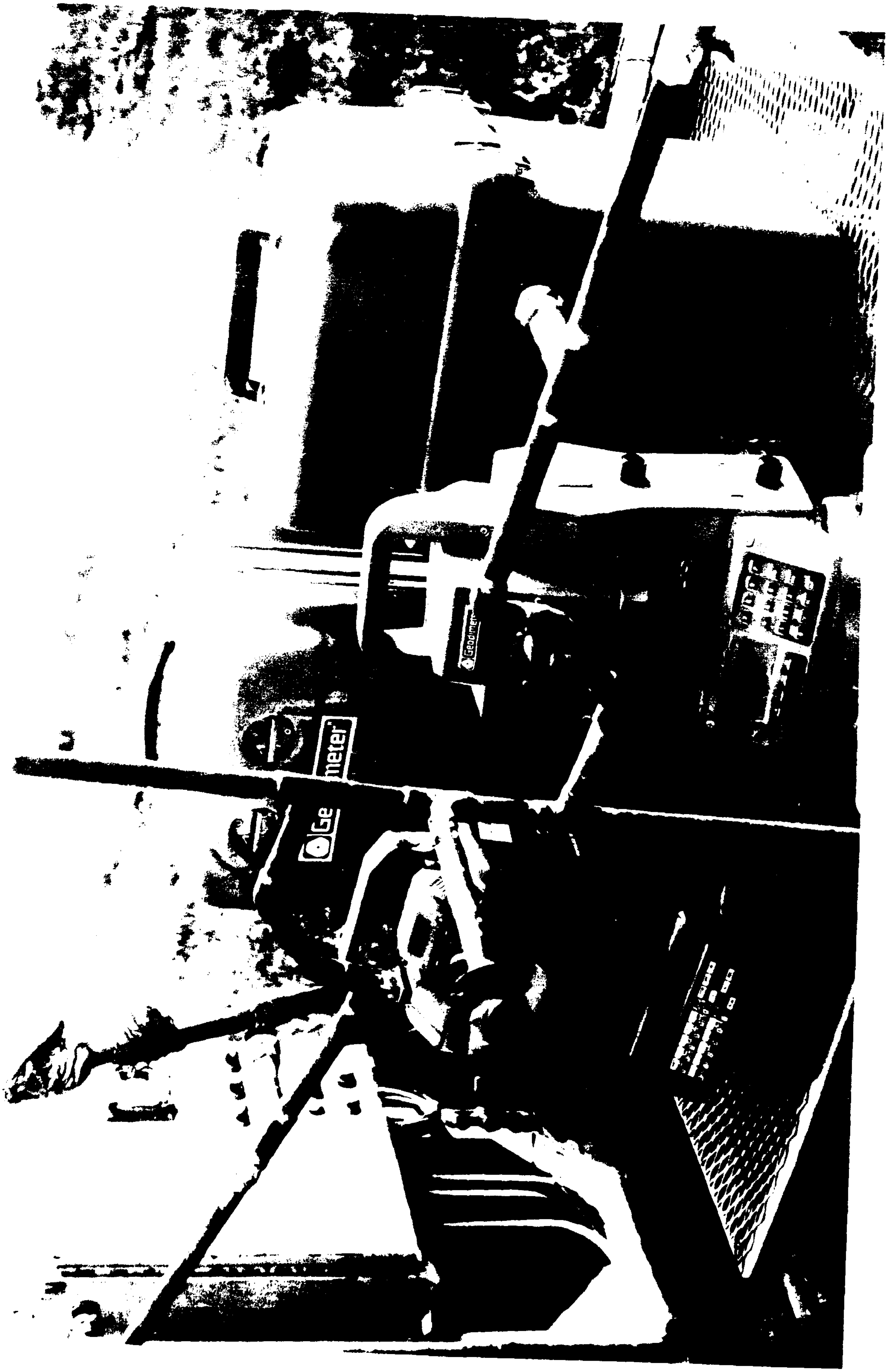

NOON
MIDNIGHT
6 PM
6 AM

APPENDIX D
Photographs

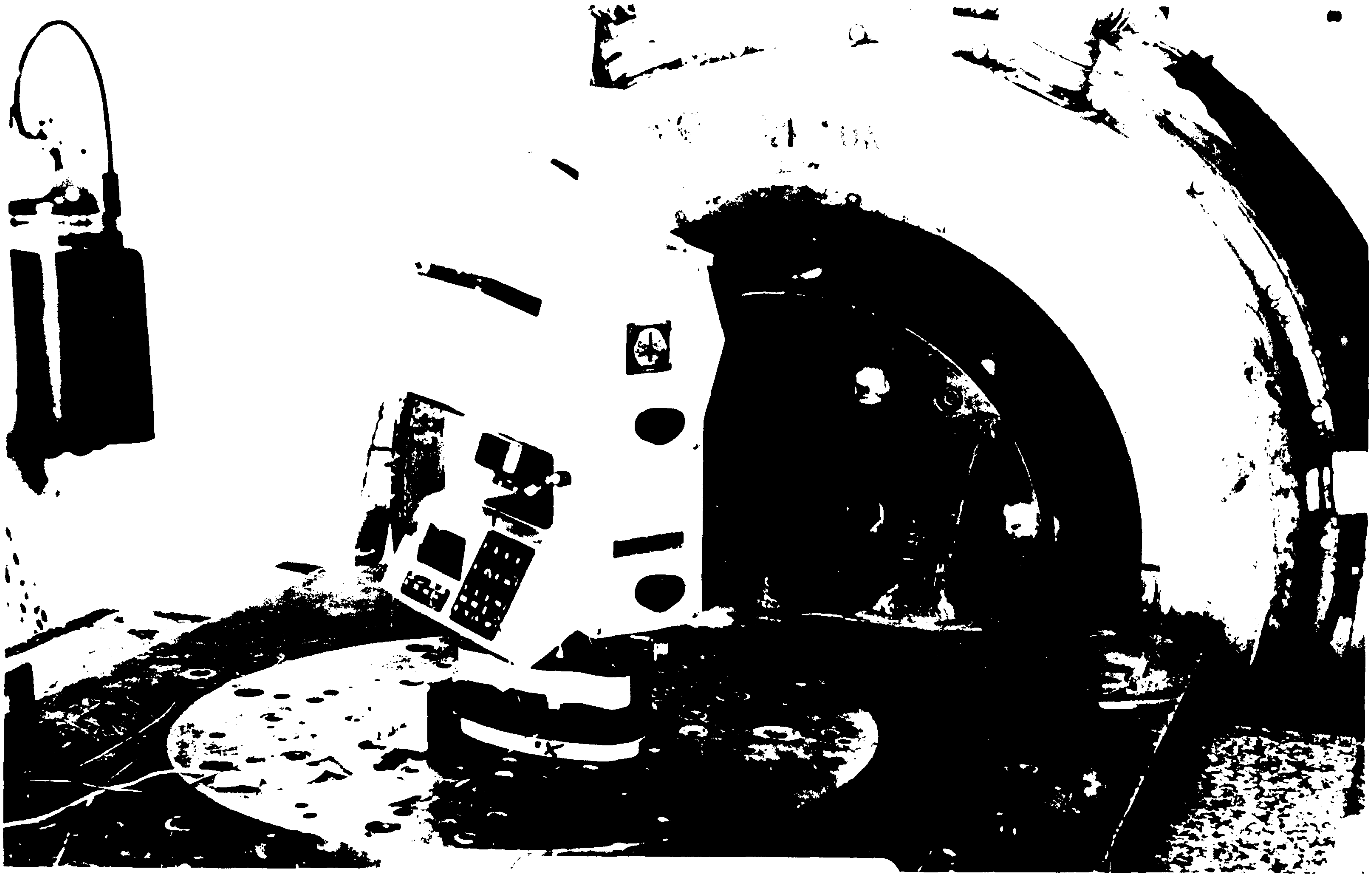


HUMIDITY

SAND AND DUST

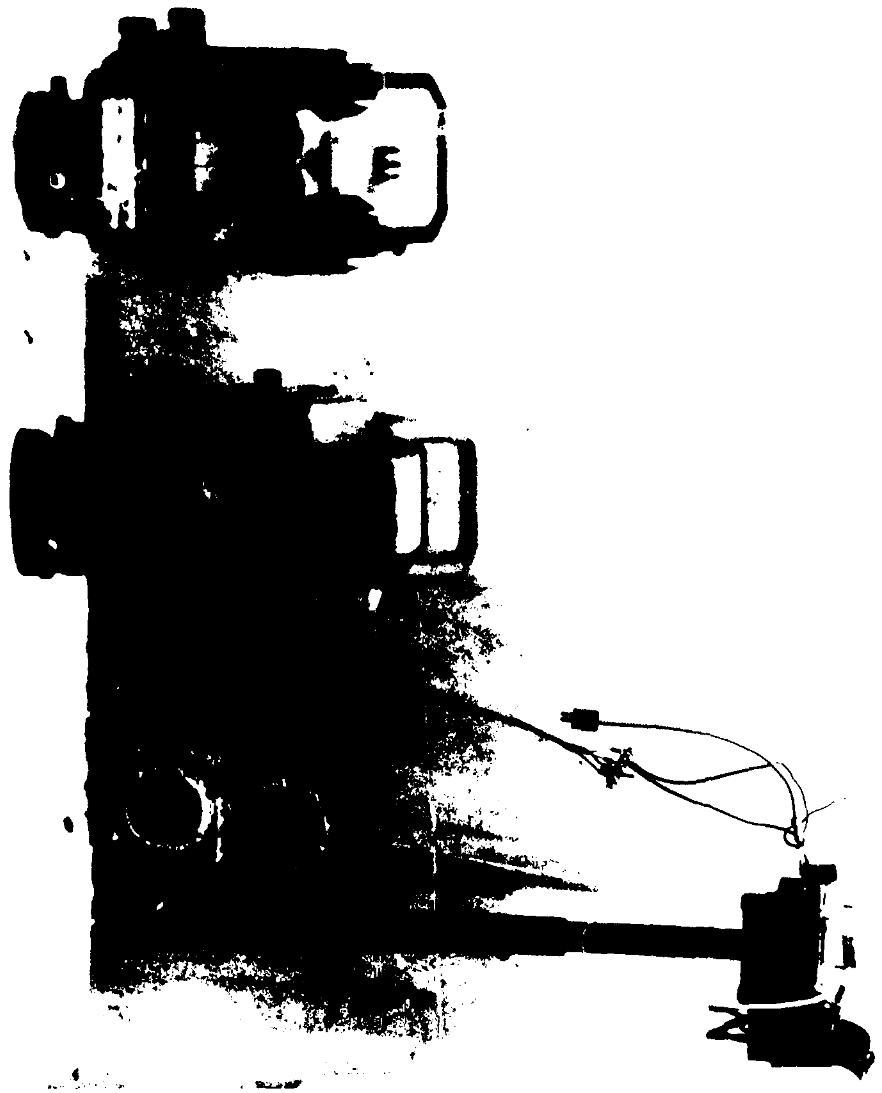



WILD T2000



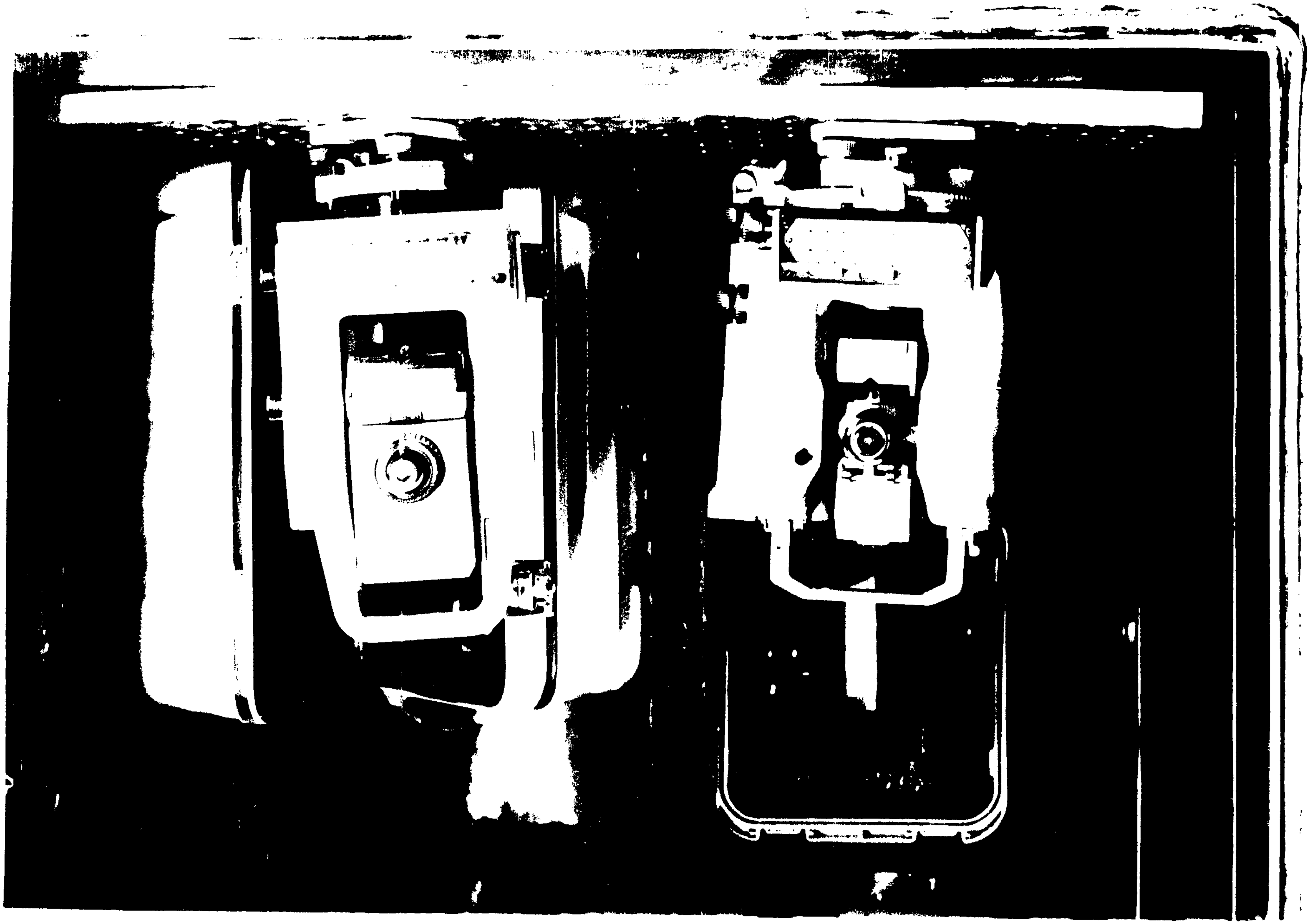
VIBRATION OUT OF CASE

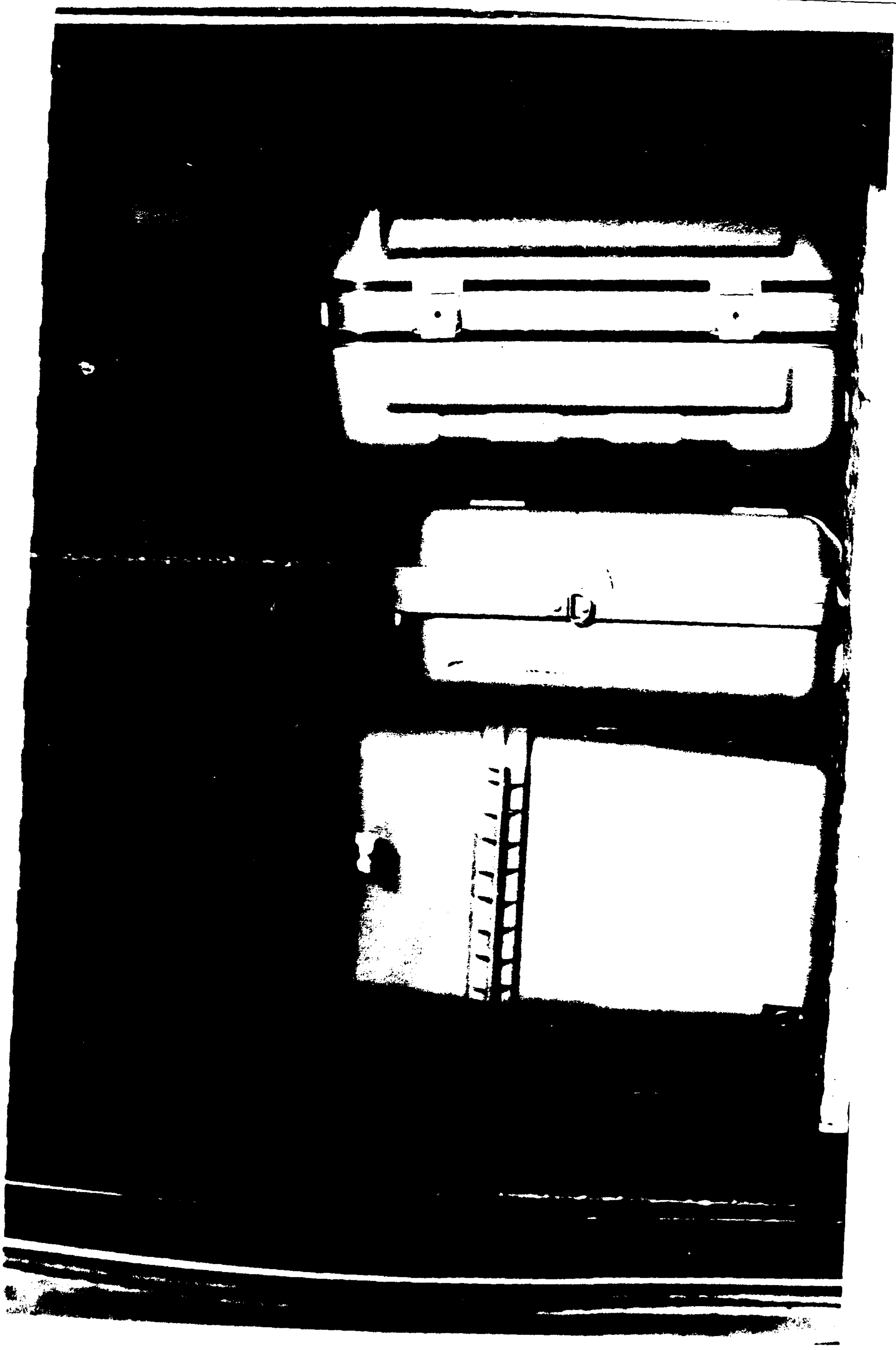
VIBRATION IN TRANSPORT CASE



SOLAR

HIGH TEMPERATURE





National Technical Systems

Report No. 555-2134
P. O. No. 011553
Date 5 November 1987

ADDENDIM
NTS/Acton Test Report 23805-88M
EMI and Magnetic Environment Testing

NTS

Test Report No. 23805-88M

No. of Pages 31

REPORT OF TEST

FOR

AUTOMATED INTEGRATED
SURVEY INSTRUMENT (AISI)

RADIAN INCORPORATED
HUNTWOOD PLAZA
ALEXANDRIA, VA 22303

Purchase Order No. 011553

Prepared by: Date 9-18-87
Michael J. Valerio, EMC Engineer
NTS/Acton
533 Main Street, Acton, MA 01720

Reviewed &
Approved by: Date 9/18/87
Ed Ramshaw, EMC Manager
NTS/Acton

MV/td:634b

TABLE OF CONTENTS

NTS

ADMINISTRATIVE DATA

1.0 PURPOSE OF TEST: The EMI test is intended to demonstrate compliance of the two electronic transits with the requirements of MIL-S-53046 for magnetic susceptibility and MIL-STD-461B Part 7 for radiated emissions testing.

2.0 MANUFACTURER: Unit #1 Geodimeter 440
Unit #2 Wild Theodolite P2000

3.0 QUANTITY OF ITEMS TESTED: One (1) of each model.

4.0 SECURITY CLASSIFICATION OF ITEMS: None

5.0 DATE TEST COMPLETED: September 4, 1987

6.0 TEST CONDUCTED BY: M. Valerio

7.0 DISPOSITION OF SPECIMENS: Returned to Radian, Inc. by Mr. John Christiansen.

1.0 APPLICABLE DOCUMENTS

MIL-STD-461	Military Standard Electromagnetic Interference Characteristics Requirements for Equipment, Subsystem, and System
MIL-STD-462	Military Standard Electromagnetic Interference Characteristics, Measurement of
MIL-STD-463A	Military Standard Definitions and Systems of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology
MIL-S-53046	Military Standard Surveying Equipment, Electronic Distance Measuring, Medium-Range, (SEDME-MR) 15 August 1984
MIL-STD-461B Part 7 As modified by Radian. See Section 8.0 Figures 8-1 and 8-2.	

2.0 TEST SAMPLE IDENTIFICATION, CONFIGURATION, AND OPERATION

2.1 Test Sample Identification

Two automated integrated survey instruments, hereafter referred to as AISI, were submitted for EMI testing. The first test sample was a Geodimeter Model 440 S/N 96569. The second test sample was a Wild Theodolite Model P2000 S/N 314195 which was equipped with a Wild Distomat Model D155 S/N 55122.

2.2 Test Sample Configuration

The AISI under test was placed on a tripod 30 inches above the facility floor. Each AISI was equipped with an onboard as well as an external battery. The external battery along with its connecting cable was positioned on stand next to the AISI during testing. The AISI under test was focused on a fixed reflector approximately 7 feet away and of equal height.

2.3 Test Sample Operation

Each AISI was tested in a tracking mode. This mode was considered to be a worst case condition with regard to both emission and susceptibility testing.

2.0 TEST SAMPLE IDENTIFICATION, CONFIGURATION, AND OPERATION (continued)

2.3.1 Test Sample Monitoring During Susceptiblity Testing

The following parameters were monitored during susceptibility testing:

- Slope Distance
- Horizontal Angle
- Vertical Angle

The criteria for susceptibility determination was based on the deviation of each parameter outside of its normal range.

3.0 SYNOPSIS OF TESTS AND RESULTS

Test Sample	Test Performed	Result
Geodimeter 440	RE02	Failed
Geodimeter 440	Magnetic Field	Passed
Wild T2000	RE02	Failed
Wild T2000	Magnetic Field	Passed

4.0 GENERAL TEST REQUIREMENTS

4.1 Description of Test Facility

The test sample and peripherals (measuring instruments) were installed within Ace Engineering shielded enclosures measuring 20'9" x 13'4" x 8'8" and 20' x 10' x 8'. (Reference 11-1. 11-2.) All power leads entering the shielded enclosures are routed via Axel radio frequency filters to provide at least 80 dB of attentuation above 10 KHz, when measured in accordance with MIL-STD-220A. Ancillary/measurement equipment was installed in an adjacent shielded enclosures measuring 10' x 8' x 7'. Interconnecting cables, as required, were routed via feedthrough ports connecting the two enclosures. Shielding effectiveness to electric fields and plane waves exceeds 80 dB from 14 KHz to 10 GHz.

4.2 Test Equipment

The test equipment proposed, or the equivalent, used during testing appears in Section 7.0 of this test report.

All test equipment was checked prior to testing to assure that it was within calibration, and was allowed sufficient time on to stabilize.

Calibration is performed and checked on a routine basis in accordance with MIL-C-45662A, using standards traceable to the National Bureau of Standards (NBS).

5.0 TEST PROCEDURE

5.1 Radiated Interference RE02 Electric Field
14 KHz to 10 GHz

Requirements

Radiated emissions from 14 KHz to 10 GHz were measured in accordance with the applicable portion of Test Method RE02 of MIL-STD-462 Notice 3.

Procedures

The AISI was set up and operated as detailed in Sections 2.2 and 2.3. The antennas used during the performance of this test were as follows:

FREQUENCY	ANTENNA	COAXIAL CABLE
0.014 - 25 MHz	41" Rod	25' of RG223/U
25 - 100 MHz	Biconical	25' of RG9/U
20 - 1000 MHz	Log Spiral	25' of RG9/U
1 GHz - 10 GHz	Duel Ridge Guide	25' of RG9/U

Measurements from 0.014 to 30 MHz were performed manually using the appropriate antenna with the corresponding cable connected an EMC-25 receiver.

Peak readings in both narrowband and broadband were recorded while the receiver was tuned over the frequency range. External attenuation, antenna factors and any conversion factors were then added to the meter reading in order to obtain a final reading. This

NTS

5.0 TEST PROCEDURE (continued)

5.1 Radiated Interference RE02 Electric Field 14 KHz to 10 GHz (continued)

Procedures (continued)

reading is then compared to the specification limit. Results appear in Section 6.0.

Measurements from 30 to 10000 MHz were performed using the appropriate antenna and corresponding coaxial cable connected to a Hewlett Packard Spectrum Analyzer Model 8566B. This analyzer is computer controlled using Hewlett Packard's 85864C EMI measurement software. Sweeps were made in both narrowband and boradband between 30 MHz and 1000 MHz. X-Y plots of noise versus frequency were generated. Signal levels were corrected by adding the antenna factors, thus showing both data and specification limit in their correct relationship. These X-Y plots appear in Section 6.0.

5.2 Magnetic Field, Susceptibility, MIL-S-53046

Requirement

Susceptibility to a magnetic field was determined in accordance with MIL-S-53046.

NTS

5.0 TEST PROCEDURE (continued)

5.2 Magnetic Field, Susceptibility, MIL-S-53046

Procedure

The equipment was located at the center of a coil of sufficient ampere-turn capacity to produce a steady-state magnetic field of 8 gauss at the center. The field was calibrated prior to placing the AISI in the field. The AISI was tested for a period of time that was sufficient to determine proper functional performance in a constant field fo 8 guass.

Ten angel and distance readings were taken with the lines of magnetic force directed as follows:

- North-South
- East-West
- Vertical

Results appear in Section 6.0.

6.0 X-Y PLOTS AND TEST DATA

National Technical Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type GEODIMETER 440

Customer RADIAN INC.

Report No 23805-88M

P.O 011503

Operator M.Valerio

Spec Mil- Std 461B

Test RE02 Narrowband

Date 9-4-87

Conditions Unit on W/both batteries

Time

FREQ.(Mhz)	Meter read (dBuV)	Atten. set	Antenna Fac (db @1M)		FINAL READ (dBuV/M)	Spec (dBuV/M)
.014	-20	0	55.0		35.0	35.0
.020	-20.	0	55.0	*	35.0	34.0
.026	-17	0	56.0	*	39.0	33.5
.032	-17	0	57.0	*	40.0	33.0
.040	-22	0	50.0		28.0	32.7
.060	-23	0	50.5		27.5	32.0
.070	-23	0	50.5		27.5	31.7
.080	-19	0	46.0		27.0	31.2
.102	+5	0	46.0	*	51.0	31.0
.108	-21	0	46.0		25.0	31.0
.140	-22	0	46.5		24.5	30.0
.204	-2	0	46.0	*	44.0	29.5
.208	-20	0	46.0		26.0	29.5
.250	-22	0	43.0		21.0	29.0
.305	0	0	42.0	*	42.0	28.5
.310	-20	0	42.0		22.0	28.5
.410	-2	0	42.0	*	40.0	28.0
.415	-20	0	42.0		22.0	28.0
.510	-10	0	38.0		28.0	27.5
.520	-20	0	38.0		18.0	27.5

* OUT OF SPEC

National Technical Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type: Geodimeter 440
Customer: RADIAN INC.
Report No: 33805-88M
P.O.: 011553
Operator: M.Valerio
Spec.: Mil- Std 461B
Test: RE02 Narrowband
Date: 9-4-87
Conditions: Unit on W/both batteries
Time:

EQ.(Mhz)	Meter read (dBμV)	Atten. set	Antenna Fac (dB@1M)		FINAL READ (dBμV/M)	Spec (dBμV/M)	
610	-10	0	38.0	*	28.0	27.0	
615	-20	0	38.0		18.0	27.0	
710	-12	0	39.0		27.0	27.0	
800	-11	0	39.0	*	28.0	26.8	
810	-22	0	39.0		17.0	26.7	
910	-12	0	39.5	*	27.5	26.5	
915	-22	0	39.5		17.5	26.5	
015	-13	0	40.0	*	27.0	26.3	
.02	-21	0	40.0		19.0	26.3	
.10	-13	0	40.0	*	27.0	26.2	
.15	-26	0	40.0		14.0	26.2	
.20	-16	0	34.0		18.0	26.1	
21	-26	0	34.0		8.0	26.1	
30	-18	0	34.0		16.0	26.1	
.40	-18	0	34.0		16.0	26.0	
50	-16	0	34.0		18.0	25.5	
60	-18	0	34.0		16.0	25.3	
70	-20	0	34.5		14.5	25.1	
80	-18	0	34.5		16.5	25.0	
90	-18	0	35.0		17.0	24.9	6 3

* OUT OF SPEC

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National Technical Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type Geodimeter 440

Customer RADIAN INC.

Report No 23805-88M

P.O. 011553

Operator M.Valerio

Spec Mil- Std 461B

Test RE02 Narrowband

Date 9-4-87

Conditions Unit on W/both batteries

Time

dBuV	dBuV		dB@1M		dBuV/M	dBuV/M	
FREQ.(Mhz)	Meter read	Atten. set	Antenna Fac		FINAL READ	SPEC	
2.0	-16	0	35.0		19.0	24.9	
2.1	-16	0	35.0		19.0	24.8	
2.2	-16	0	35.0		19.0	24.7	
2.32	-16	0	30.0		14.0	24.6	
2.5	-1	0	30.0	*	29.0	24.5	
2.7	+1	0	30.5	*	31.5	24.2	
3.0	+2	0	30.5	*	32.5	24.0	
3.5	-4	0	31.0	*	27.0	23.8	
3.52	-8	0	31.0		23.0	23.8	
4.0	-11	0	31.5		20.5	23.5	
5.0	-12	0	30.0		18.0	23.0	
8.0	-16	0	28.0		12.0	22.2	
10.0	-12	0	28.0		16.0	21.7	
12.0	-13	0	28.0		15.0	21.5	
19.0	-7	0	24.0		17.0	20.3	
25.0	-13	0	26.0		13.0	20.0	
30.0	-12	0	27.0		15.0	21.3	

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Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

ype WILD P2000

epon No 23805-88M

perator M.Valerio

est RE02 Narrowband

onditions unit on w/both batteries

ime

Customer RADIAN INC.

P O 011353

Spec Mil- Std 461B

Date 3-4-37

.(Mhz)	Meter read (dBμV)	Atten. set	Antenna Fac (dB@1M)		FINAL READ (dBμV/M)	SPEC (dBμV/M)	
14	-10	0	55.0	*	45.0	35.0	
20	-20	0	55.0	*	35.0	34.0	
26	-14	0	56.0	*	42.0	33.5	
32	-18	0	57.0	*	39.0	33.0	
45	-22	0	50.0		28.0	32.5	
60	-26	0	50.0		24.0	32.0	
75	-26	0	46.0		20.0	31.5	
90	-19	0	46.0		27.0	31.0	
.0	-22	0	46.0		24.0	30.5	
.0	-25	0	47.0		22.0	30.0	
0	-22	0	46.0		24.0	29.5	
.0	-24	0	46.0		22.0	29.3	
.0	-25	0	42.5		17.5	29.2	
12	-18	0	42.0		24.0	28.5	
50	-22	0	42.0		20.0	28.0	
00	-23	0	38.5		15.5	27.5	
0	-22	0	39.0		17.0	27.0	
0	-21	0	39.5		18.5	26.5	
)	-22	0	40.0		18.0	26.3	
1	-24	0	34.0		10.0	26.0	6 5

* OUT OF SPEC

National Technical Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type: Wild P2000

Customer: RADIAN INC.

Report No: 23805-88M

P.O.: 011553

Operator: M.Valerio

Spec.: Mil- Std 461B

Test: RE02 Narrowband

Date: 9-4-87

Conditions: Unit on W/both batteries

Time:

FREQ.(Mhz)	Meter read dBµV	Atten. set	Antenna Fac dB/M		FINAL READ dBµV/M	Spec dBµV/M
1.6	-20	0	34.0		14.0	25.3
2.3	-19.	0	35.0		16.0	24.6
3.0	-13	0	30.5		17.5	24.0
4.5	-15	0	32.0		17.0	23.3
5.5	-16	0	27.0		11.0	23.0
7.0	-18	0	27.5		9.5	22.5
7.3	-10	0	28.0		18.0	22.4
9.0	-10	0	28.0		18.0	22.0
9.8	-9	0	28.0		19.0	21.9
11.3	-5	0	28.0	*	23.0	21.6
12.3	+1	0	23.0	*	24.0	21.4
13.0	+4	0	23.0	*	27.0	21.3
14.5	+16	0	23.0	*	39.0	21.1
16.8	+18	0	24.0	*	42.0	20.9
18.7	+12	0	24.0	*	36.0	20.6
19.4	+14	0	24.0	*	38.0	20.3
20.0	-10	0	24.5		14.5	20.3
21.0	-14	0	25.0		11.0	20.2
30.0	-12	0	27.0		15.0	21.3

* OUT OF SPEC

National Technical Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type: GEODIMETER 440

Customer: RADIAN INC.

Report No: 00005-88M

P O: 011503

Operator: [illegible]

Spec: Mil-Std 461B

Test: RE02 Broadband

Date: 3-4-87

Conditions: Unit on w/ both batteries

Time:

FREQ. (Mhz)	METER READ (dBμV/MHz)	ATTEN. SET	ANTENNA FAC (dB@1M)	BB CONVER. (dB)		FINAL READ (dBμV/MHz/M)	Spec (dBμV/MHz/M)
.014	-8	0	55.0	45		92.0	100.0
.020	-13	0	55.0	45		87.0	98.0
.030	-10	0	57.0	45		92.0	96.0
.040	-14	0	50.0	44		80.0	95.0
.060	-18	0	50.5	44		76.5	93.0
.075	-18	0	50.5	44		76.5	92.0
.090	-10	0	46.0	44		80.0	91.0
.110	-10	0	46.0	44		80.0	90.0
.140	-14	0	46.0	44		76.0	89.0
.180	-14	0	46.0	43		75.0	88.0
.210	-13	0	46.0	43		76.0	87.3
.260	-14	0	46.0	43		75.0	86.0
.290	-10	0	42.0	43		75.0	85.8
.450	-10	0	42.0	43		75.0	84.0
.600	-6	0	38.0	43		75.0	82.0
.700	-7	0	38.5	43		74.5	81.5
.800	-5	0	39.0	43		77.0	81.0
.908	-6	0	39.0	43		76.0	80.5
1.015	-7	0	40.0	43		76.0	80.0
1.10	-10	0	34.0	43		67.0	79.5

NTS

National Technical Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type WILD P2000

Customer RADIAN INC.

Report No 23805-88M

P.O. J11553

Operator M.Valerio

Spec. Mil- Std 461B

Test RE02 Narrowband

Date 9-4-87

Conditions Unit on W/both batteries

Time

FREQ.(Mhz)	Meter read dBuV	Atten. set	Antenna Fac dB@/M		FINAL READ dBuV/M	SPEC dBuV/M	
1.6	- 20	0	34.0		14.0	25.3	
2.3	- 19.	0	35.0		16.0	24.6	
3.0	- 13	0	30.5		17.5	24.0	
4.5	- 15	0	32.0		17.0	23.3	
5.5	- 16	0	27.0		11.0	23.0	
7.0	- 18	0	27.5		9.5	22.5	
7.3	- 10	0	28.0		18.0	22.4	
9.0	- 10	0	28.0		18.0	22.0	
9.8	- 9	0	28.0		19.0	21.9	
11.3	- 5	0	28.0	*	23.0	21.6	
12.3	+ 1	0	23.0	*	24.0	21.4	
13.0	+ 4	0	23.0	*	27.0	21.3	
14.5	+ 16	0	23.0	*	39.0	21.1	
16.8	+ 18	0	24.0	*	42.0	20.9	
18.7	+ 12	0	24.0	*	36.0	20.6	
19.4	+ 14	0	24.0	*	38.0	20.3	
20.0	- 10	0	24.5		14.5	20.3	
21.0	- 14	0	25.0		11.0	20.2	
30.0	- 12	0	27.0		15.0	21.3	

* OUT OF SPEC

NTS

National Technical Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type WILD P2000

Customer RADIAN INC.

Report No 00005-86M

P.O. 011533

Operator M. Valerio

Spec. Mil-Std 461B

Test RE02 Broadband

Date 9-4-87

Conditions Unit on w/ both batteries

Time

FREQ. Mhz	METER READ dBuV/MHz	ATTEN. SET	ANTENNA FAC dB/M	BB CONVER.		FINAL READ dBuV/MHz	Spec dBuV/MHz
014	-6	0	55.0	45		94.0	100.0
020	-12	0	55.0	45		88.0	98.0
030	-8	0	57.0	45		94.0	96.0
050	-14	0	50.0	44		80.0	94.0
060	-14	0	50.0	44		80.0	93.0
075	-14	0	46.0	44		76.0	92.0
080	-10	0	46.0	44		80.0	92.0
120	-13	0	46.0	44		77.0	89.8
150	-13	0	47.0	44		78.0	88.5
180	-13	0	46.0	43		76.0	88.0
220	-13	0	46.0	43		76.0	87.0
260	-13	0	42.5	43		72.5	86.0
350	-10	0	42.0	43		75.0	85.0
450	-11	0	42.0	43		74.0	84.0
500	-11	0	38.5	43		70.5	83.0
700	-12	0	39.0	43		70.0	81.5
100	-12	0	39.5	43		70.5	80.5
10	-11	0	40.0	43		72.0	79.5
40	-14	0	34.0	43		63.0	78.3
80	-12	0	34.5	43		65.5	77.2

NTS

National
Technical
Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

Type Wild P2000

Customer RADIAN INC.

Report No 22805-88M

P.O 011533

Operator M.Valerio

Spec Mil-Std 461B

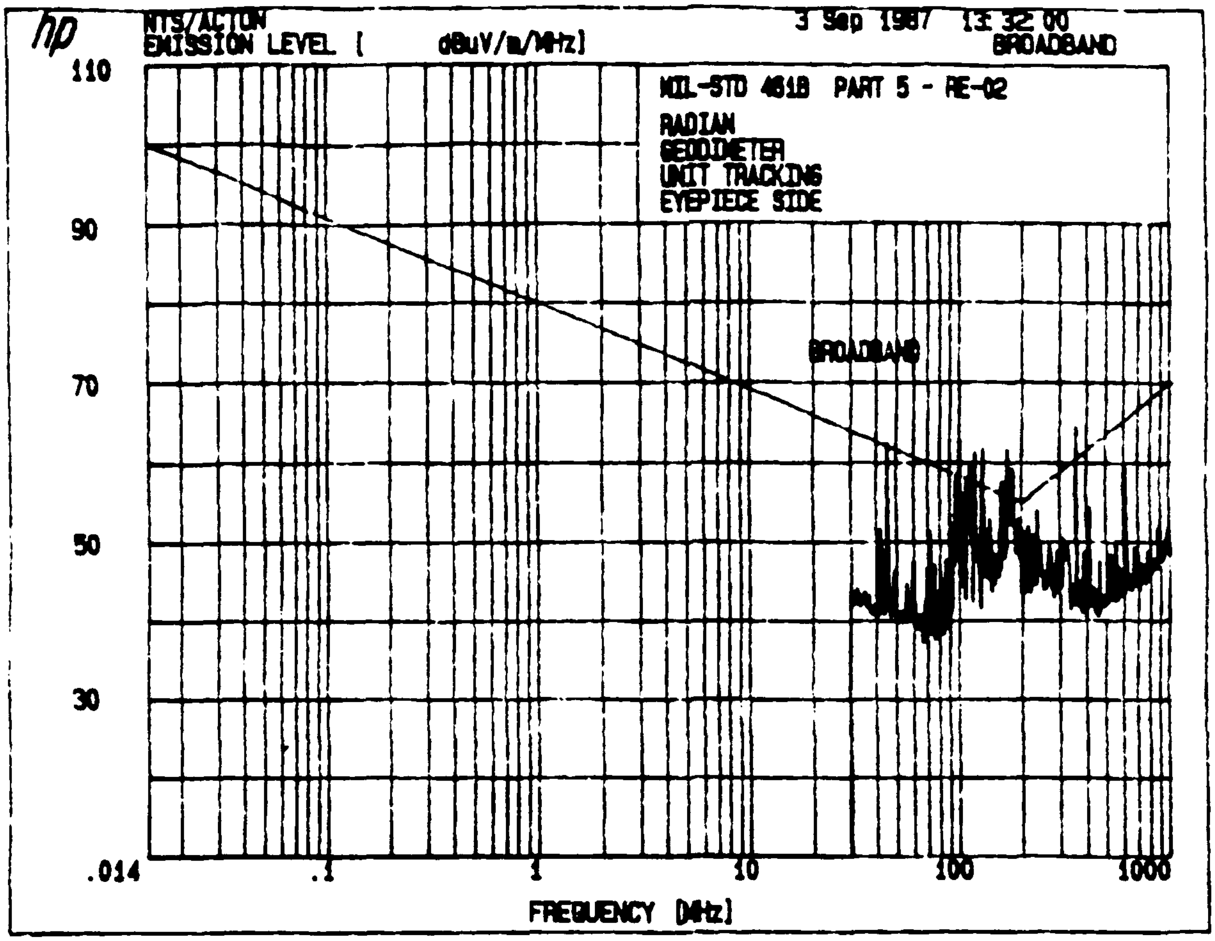
Test RE02 Broadband

Date 9-4-87

Conditions Unit on W/ both batteries

Time

FREQ. (Mhz)	METER READ dBμV/MHz	ATTEN. SET	ANTENNA FAC dB @1M	BB CONVER. dB		FINAL READ dBμV/MHz/M	Spec dBμV/MHz
2.30	-10	0	30.0	43		63.0	76.
2.70	-6	0	30.5	25		49.5	75
5.0	-6	0	30.0	25		49.0	72
5.5	-9	0	30.0	25		46.0	71.
7.3	-7	0	28.0	26		47.0	70.
9.0	-2	0	28.0	26		52.0	69.5
11.0	0	0	28.0	26		54.0	68.
20.0	0	0	24.5	26		505	65.
25.0	-2	0	26.0	26		50.0	64.
30.0	0	0	27.0	26		53.0	64.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MIL-STD 461B PART 5 - RE-02
RADIAN
GEODIMETER
UNIT TRACKING
EYEPIECE SIDE
BROADBAND
110
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70
50
30
.014
.1
1
10
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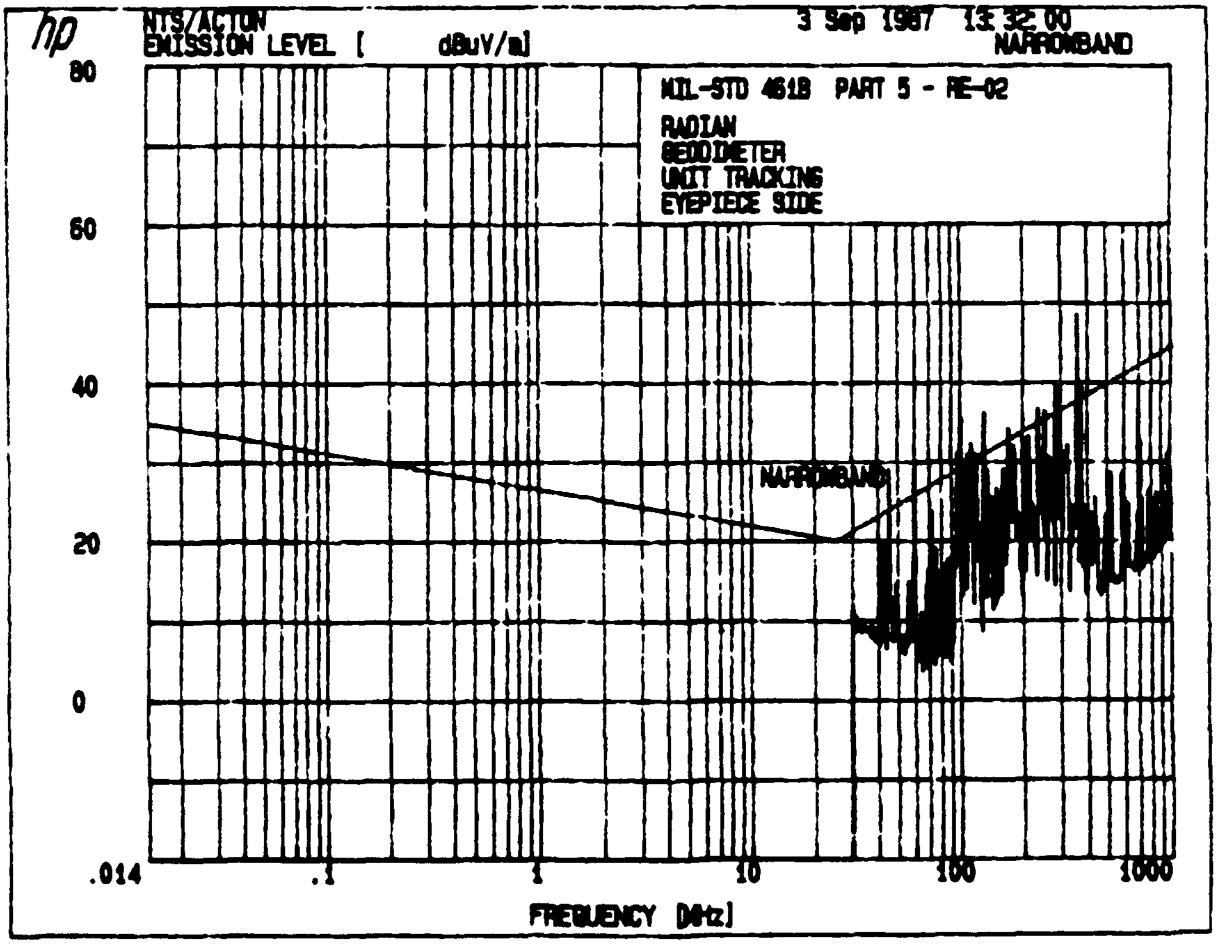
1000
FREQUENCY [MHz]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RADIAN
GEODIMETER
UNIT TRACKING
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NARROWBAND
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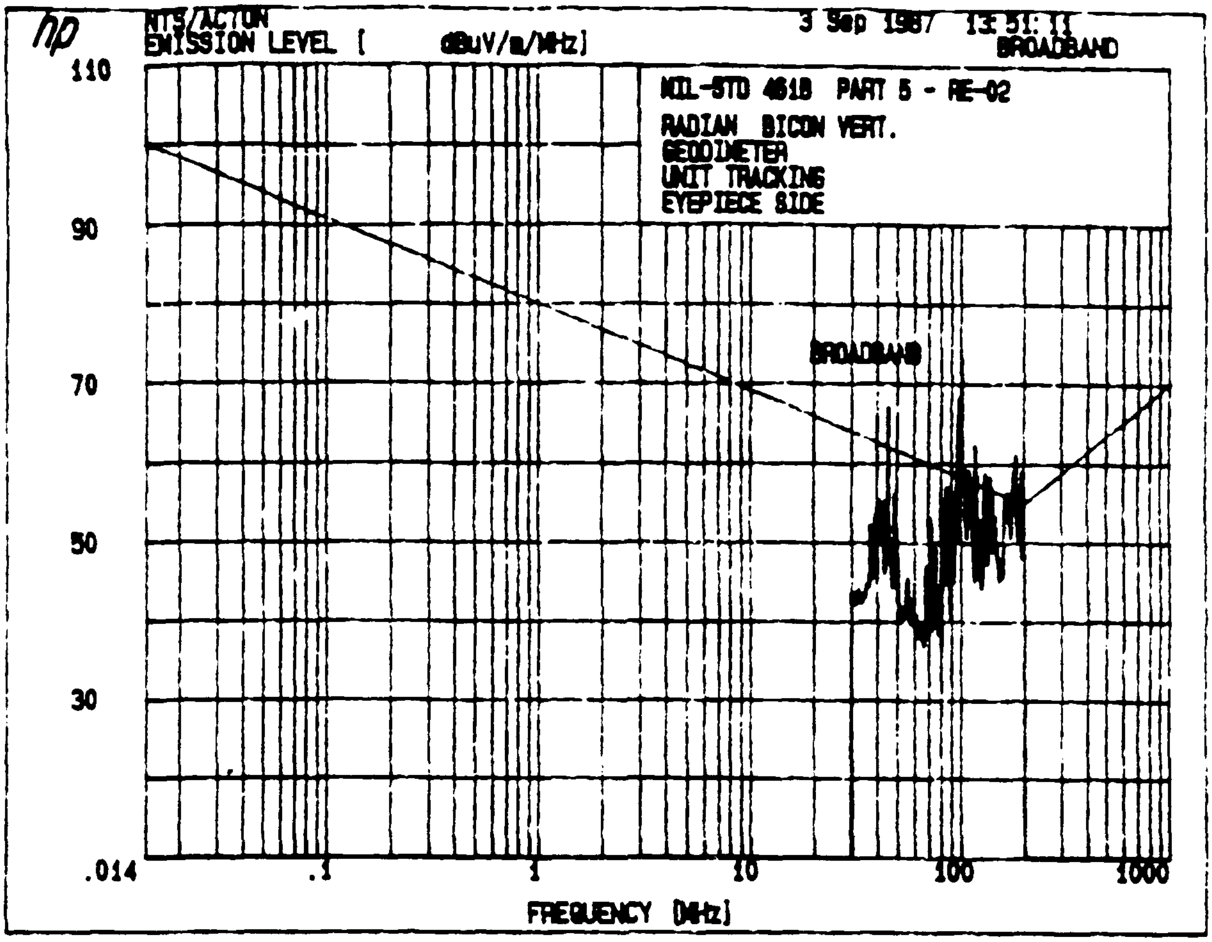
1000
FREQUENCY [MHz]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RADIAN BICON VERT.
GEODIMETER
UNIT TRACKING
EYEPIECE SIDE
BROADBAND
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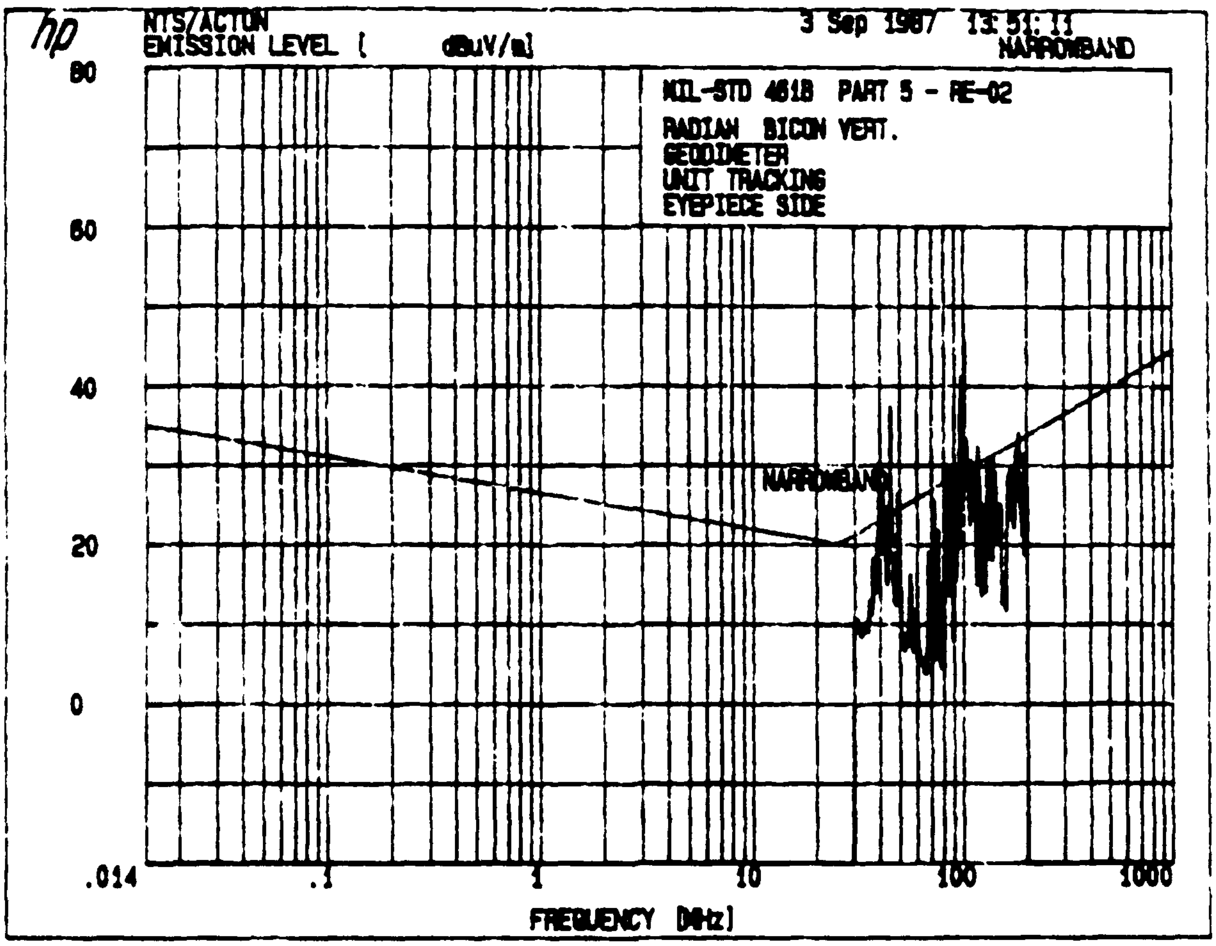
FREQUENCY [MHz]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RADIAN BICON VERT.
GEODIMETER
UNIT TRACKING
EYEPIECE SIDE
NARROWBAND
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.014
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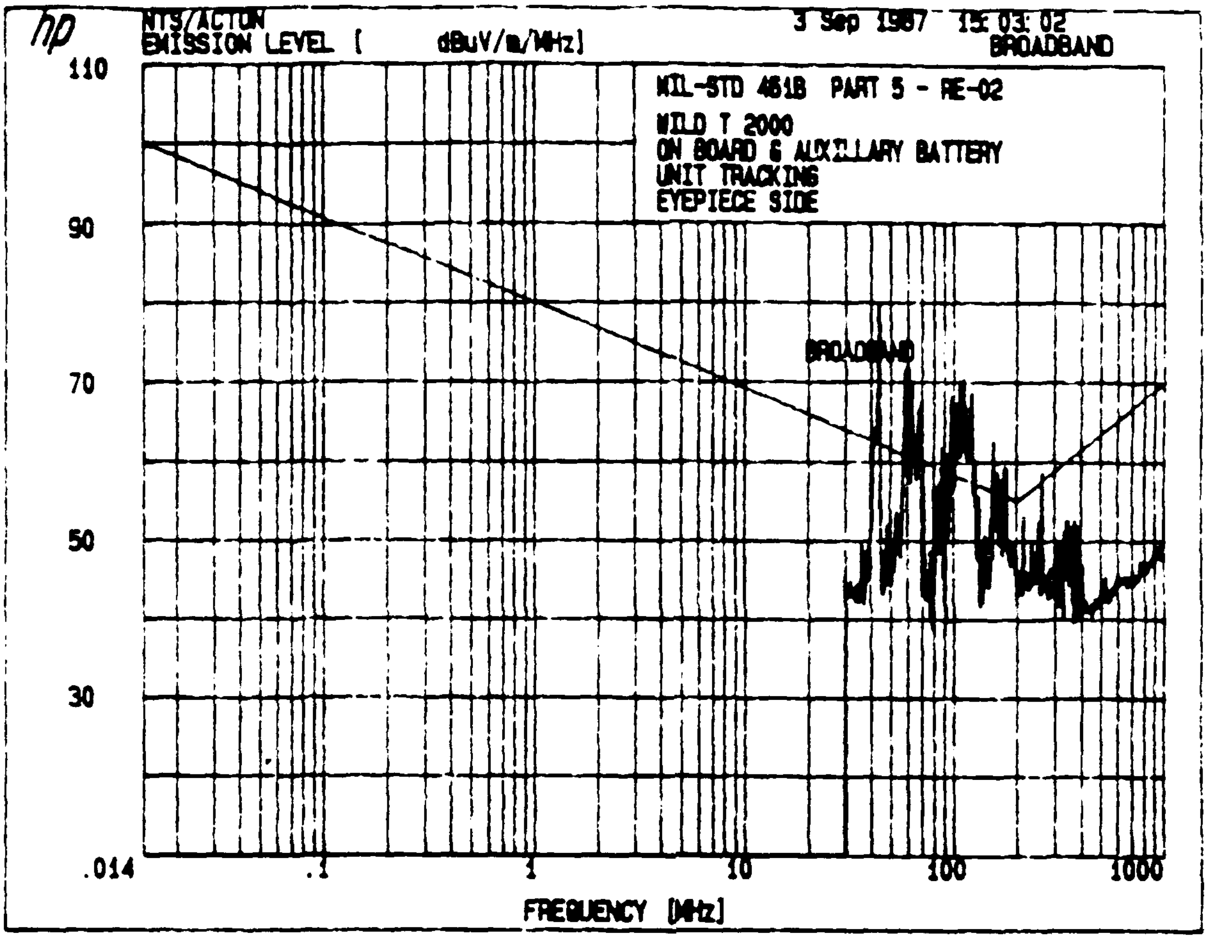
1000
FREQUENCY [MHz]



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BROADBAND
MIL-STD 461B PART 5 - RE-02
WILD T 2000
ON BOARD & AUXILLARY BATTERY
UNIT TRACKING
EYEPIECE SIDE
BROADBAND
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.014
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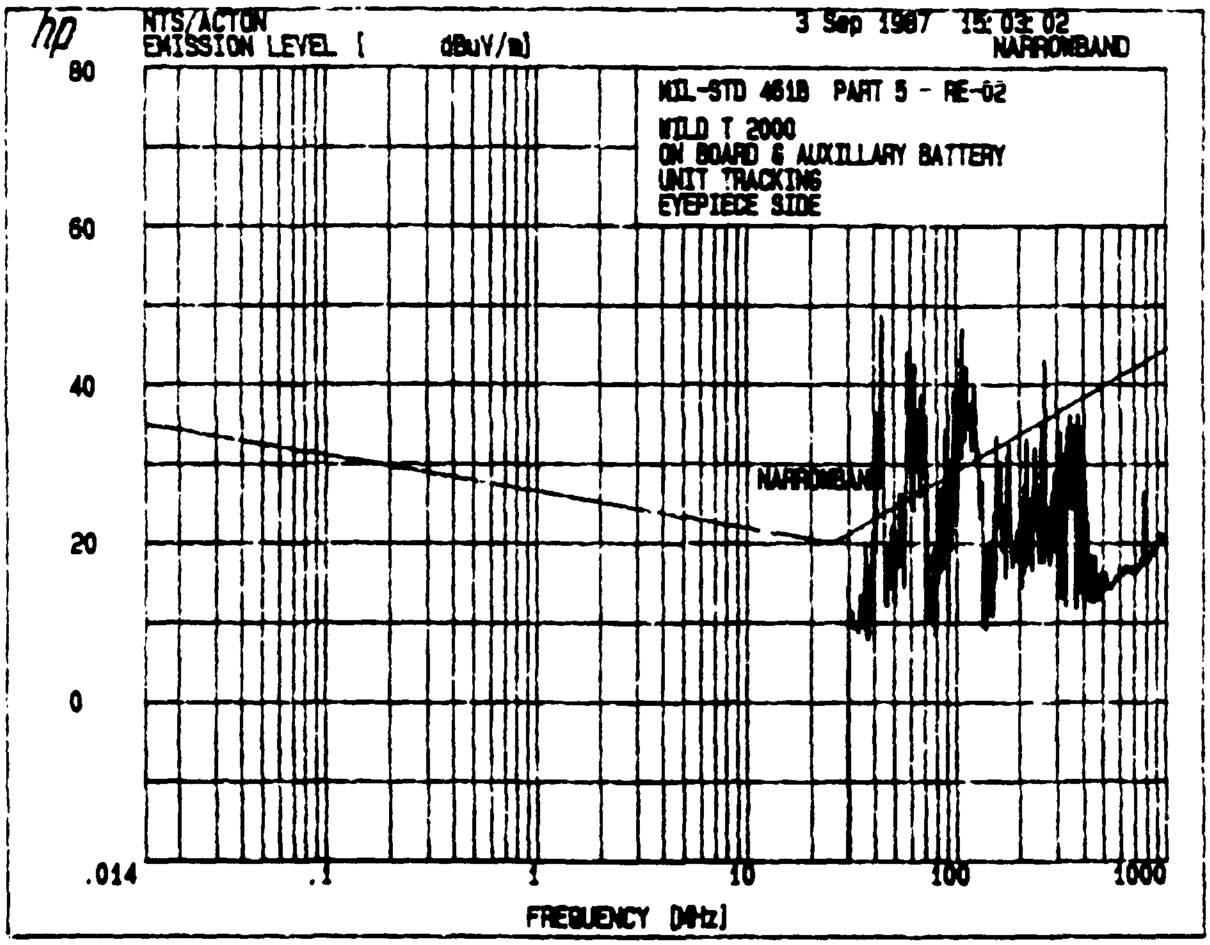
FREQUENCY [MHz]



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MIL-STD 461B PART 5 - RE-02
WILD T 2000
ON BOARD & AUXILLARY BATTERY
UNIT TRACKING
EYEPIECE SIDE
NARROWBAND
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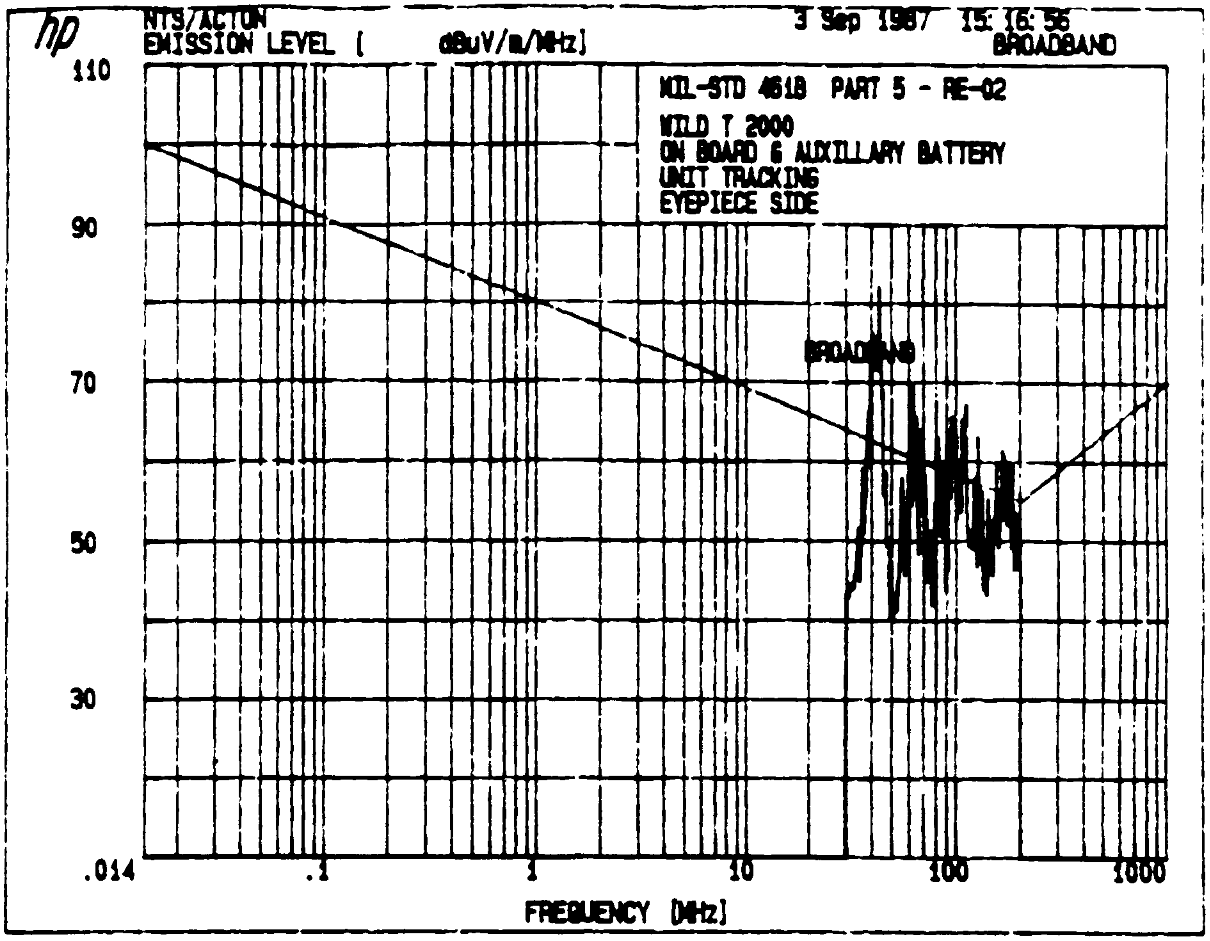
FREQUENCY [MHz]

6 13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MIL-STD 461B PART 5 - RE-02
WILD T 2000
ON BOARD & AUXILLARY BATTERY
UNIT TRACKING
EYEPIECE SIDE
BROADBAND
110
90
70
50
30
.014
.1
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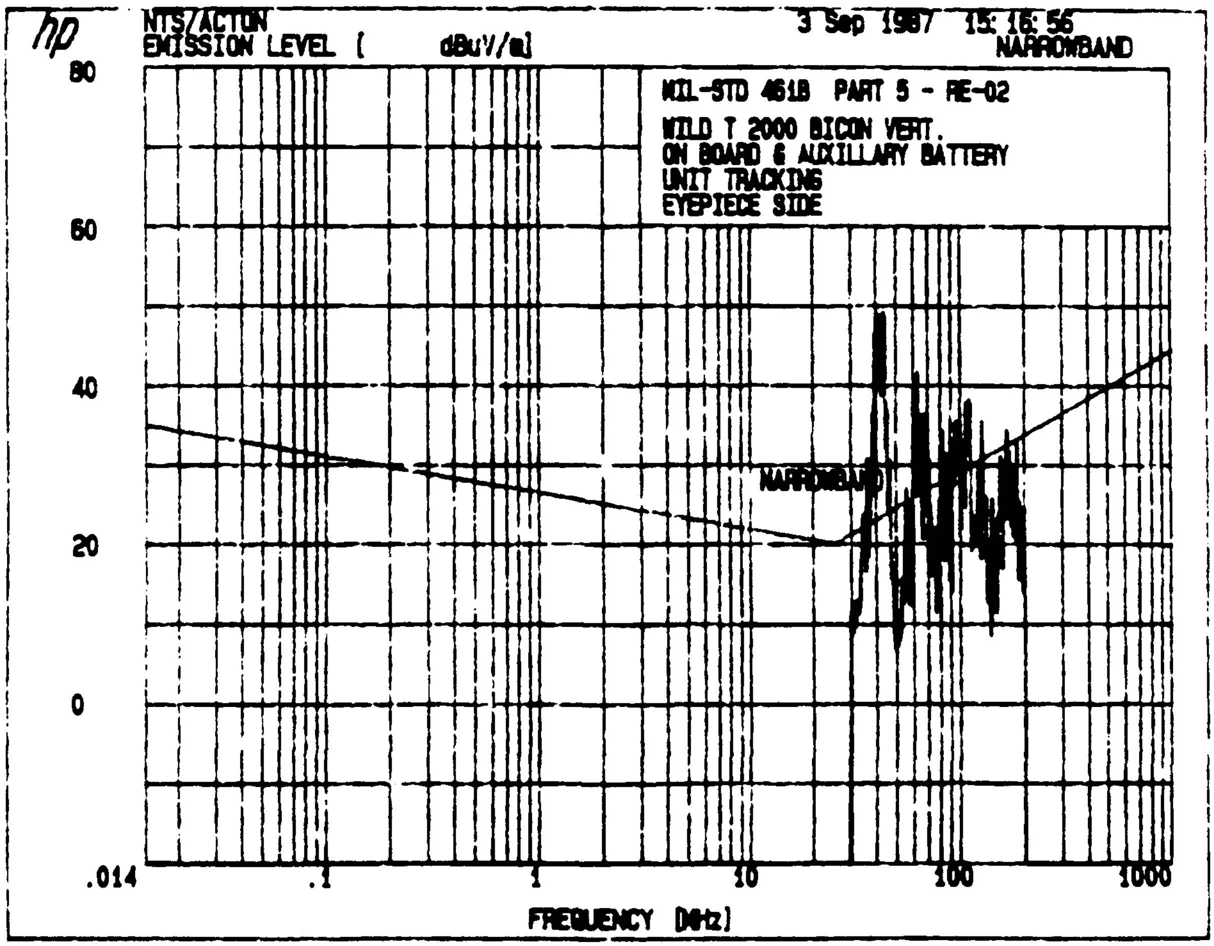
1000
FREQUENCY [MHz]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MIL-STD 461B PART 5 - RE-02
WILD T 2000 BICON VERT.
ON BOARD & AUXILLARY BATTERY
UNIT TRACKING
EYEPIECE SIDE
NARROWBAND
80
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40
20
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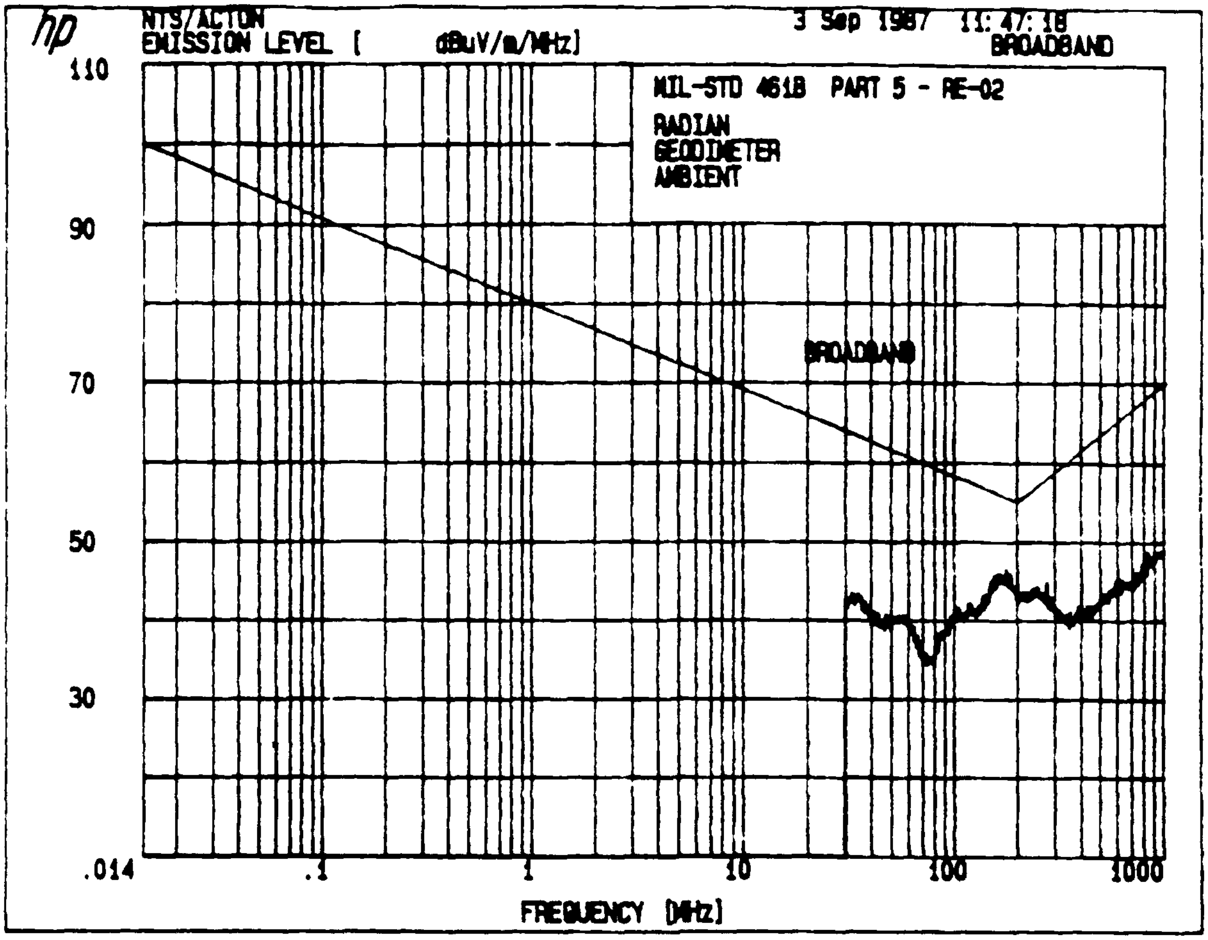
.014
.1
1
10
100
1000
FREQUENCY [MHz]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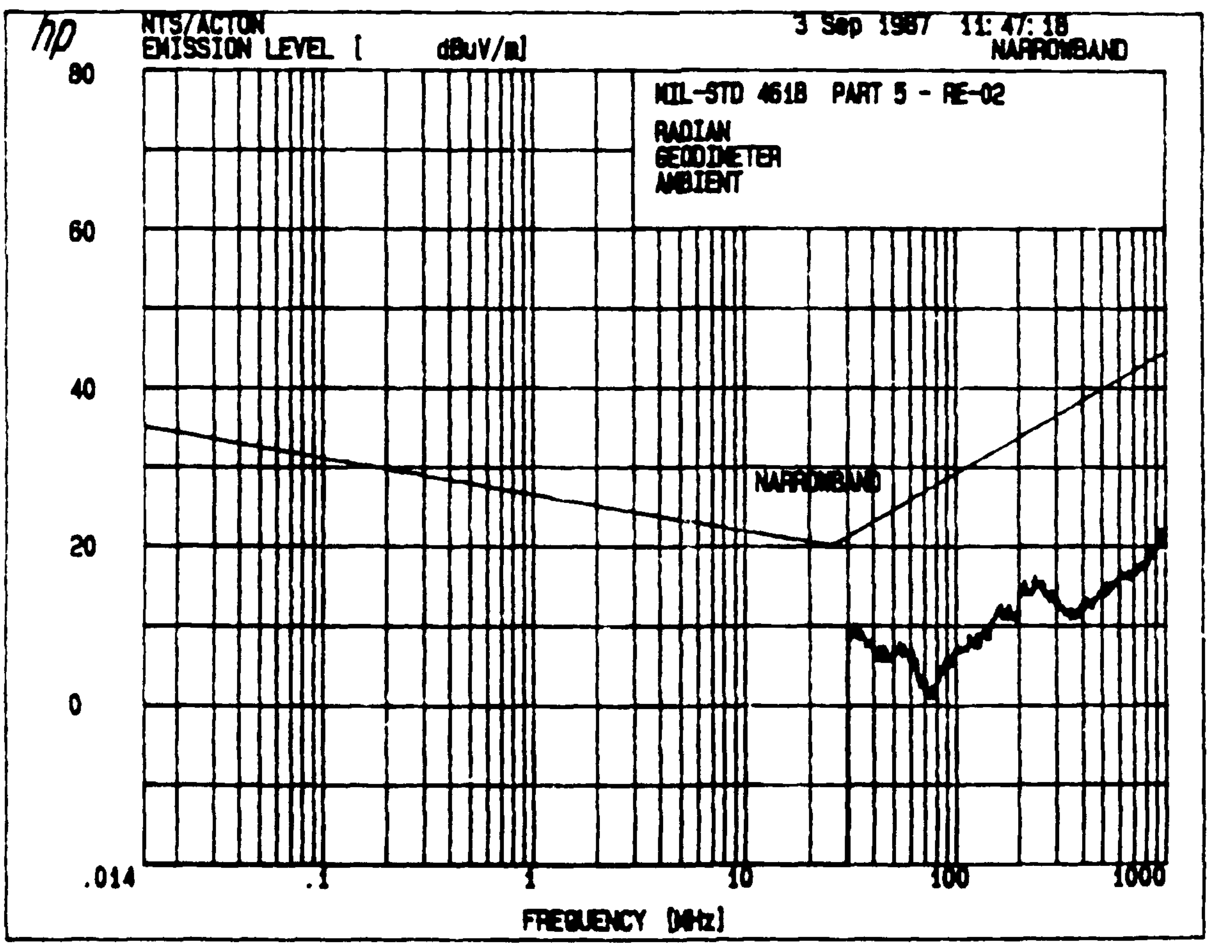
MIL-STD 461B PART 5 - RE-02
RADIAN
GEODIMETER
AMBIENT
BROADBAND
110
90
70
50
30
.014
.1
1
10
100
1000
FREQUENCY [MHz]


hp
NTS/ACTON
EMISSION LEVEL [dBuV/m]
3 Sep 1987 11:47:18
NARROWBAND
MIL-STD 461B PART 5 - RE-02
RADIAN
GEODIMETER
AMBIENT
NARROWBAND
80
60
40
20
0
.014
.1
1
10
100
1000
FREQUENCY [MHz]

NTS
National
Technical
Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

ELECTROMAGNETIC INTERFERENCE

Date ______

Customer RADIAN INC. Job # 23805-88M P.O. # 011553

Equip Under Test WILD AISI Model P2000. S/N 314195

Test Spec's. Mil-S- 53046 Test MAGNETIC ENVIORNMENT

Conditions : AISI was placed in a field of 3 Gauss. Distance readings were made with the lines of magnetic force in the following directions: North-South, East-West, and Vertical.

Conducted by: M.VALERIO

AT NO TIME DURING THE EVENT OF THIS TEST DID THE AISI EXHIBIT ANY FORM OF MALFUNCTION OR DEGRADATION OF PERFORMANCE.

National
Technical
Systems

Acton Division
533 Main Street
Acton, MA 01720

DATA SHEET

ELECTROMAGNETIC INTERFERENCE

Date ____________

Customer RADIAN INC. Job # 23805-88M P.O. # 011553

Equip Under Test GEODIMETER AISI Model 440 S/N 69569

Test Spec's. Mil-S- 53046 Test MAGNETIC ENVIONMENT

Conditions : AISI was placed in a magnetic field of 8 Gauss. Distance readings were made with the lines of magnetic force in the following directions: North-South, East-West, and Vertical.

Conducted by: M.VALERIO

AT NO TIME DURING THE EVENT OF THIS TEST DID THE AISI EXHIBIT ANY FORM OF MALFUNCTION OR DEGRADATION OF PERFORMANCE.

7.0 TEST EQUIPMENT LIST

TEST EQUIPMENT LIST

NAME	MFR.	MODEL	SER.NO.	RANGE	ACCURACY	INV.#	CAL FREQ.
41" Rod Vertical Antenna	Electro-Metrics	RVR-25	345	10 KHz to 30 MHz	N/A	AN315	NCR
Spectrum Surveillance System	Electro-Metrics	FSS250	088	20 Hz to 1.0 GHz/16 band	±3%	WA395	6 months
Gauss Meter	RFL	1890	139	1-20K Gauss		ML322	N/A
Bicon. Antenna	EMCO	3104	3254	20 MHz-200 MHz		AN339	N/A
Log Spiral Antenna	EMCO	3101	3115	200 MHz-1000 MHz		AN338	N/A
Ridge Guide Antenna	EMCO	RGA-50/60	2661	1 GHz-18 GHz		AN341	N/A
Spectrum Analyzer	Hewlett Packard	85660B	2637A03960	100 Hz to 22 GHz	See Mfr Spec	WA419A	6 months
Display	Hewlett Packard	85662A	2648A14030	100 Hz to 22 GHz	See Mfr Spec	WA419B	6 months
Quasi-Peak Adapter	Hewlett Packard	85650A	2521A00882	10 KHz to 1 GHz	See Mfr Spec	WA419C	6 months
Printer	Hewlett Packard	2225A	2711S30085	N/A	N/A	WA419D	NCR
CPU	Hewlett Packard	310	2650A16374	N/A	N/A	WA419E	NCR

TEST EQUIPMENT LIST

NAME	MFR.	MODEL	SER.NO.	RANGE	ACCURACY	INV.#	CAL FREQ.
Disk Drive	Hewlett Packard	9153B	2647A02231	N/A	N/A	WA419F	NCR
Color Monitor	Hewlett Packard	35741A	8702J23017	N/A	N/A	WA419G	NCR
Keyboard	Hewlett Packard	46021A	2643S20718	N/A	N/A	WA419H	NCR
Control Knob	Hewlett Packard	46083A	None	N/A	N/A	WA419I	NCR
Plotter	Hewlett Packard	7475A	2641V10784	N/A	N/A	WA419J	NCR

Calibration Abbreviations

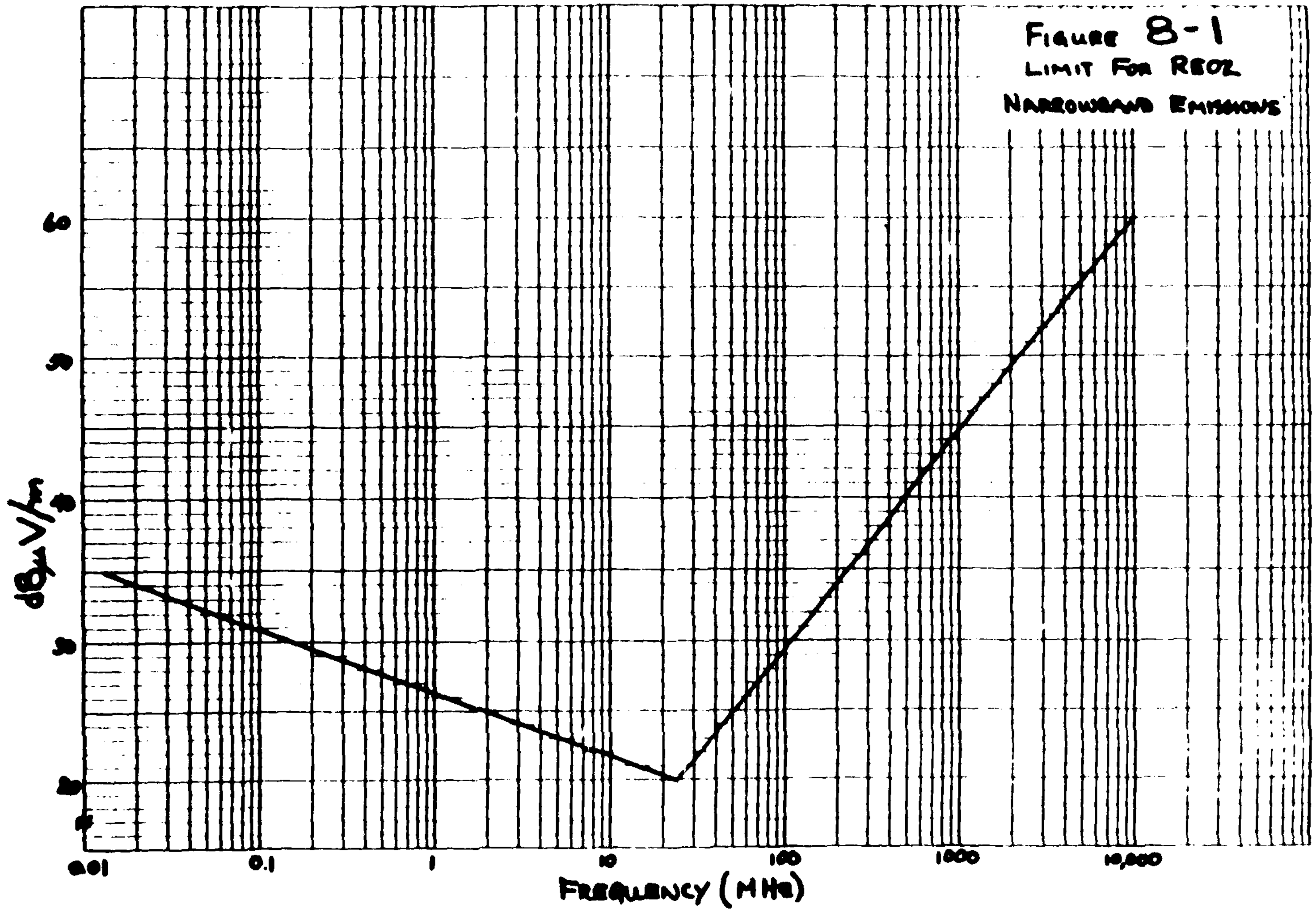
UWCE - Use With Calibrated Equipment

NCR - No Calibration Required

NQM - Not for Quantitative Measurement

CBU - Calibrate Before Use

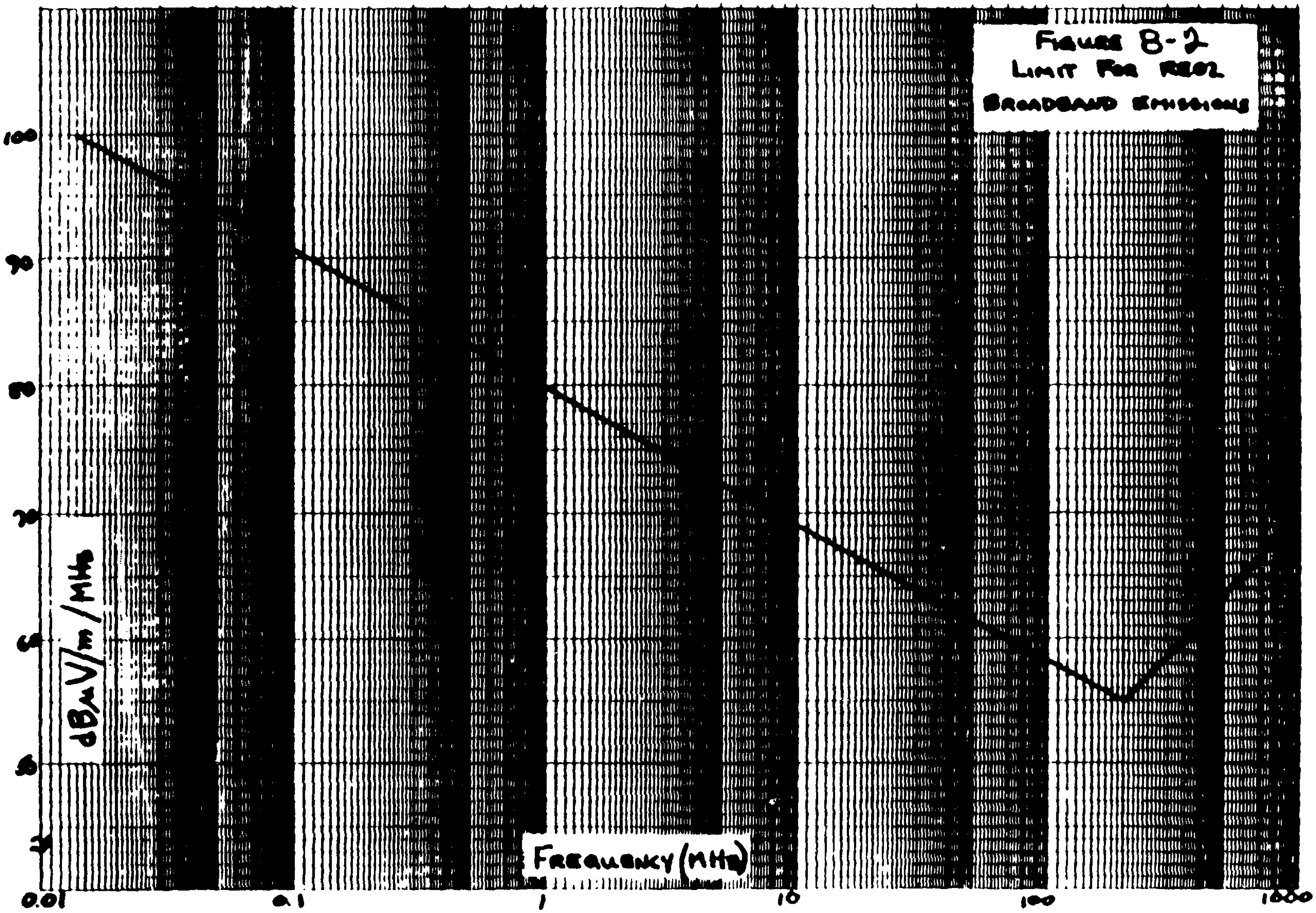
8.0 TEST SPECIFICATION CURVES



Limit for RE02 narrowband emissions.

Figure 8-1

8 2



Limit for RE02 broadband emissions.

FIGURE 8-2

8 c

National Technical Systems

RELIABILITY TESTING/ELECTRONIC CYCLING TESTING
OF
AUTOMATED INTEGRATED SURVEY INSTRUMENTS
(AISI's)

ADDENDUM 2

Report No. 555-2104A
P. O. No. 01937
Date 31 December 1987

National
Technical
Systems

RELIABILITY TESTING/ELECTRONIC CYCLING TESTING
OF
AUTOMATED INTEGRATED SURVEY INSTRUMENTS
(AISI's)

ADDENDUM 2

PREPARED FOR: RADIAN, INC.
Huntwood Plaza
5845 Richmond Highway
Alexandria, VA 22303

PREPARED BY: NATIONAL TECHNICAL SYSTEMS
DC Division
State Route 748
Hartwood, VA 22471

National Technical Systems

REVISION PAGE

Rev. No.	Date	Page No.	Para. No.	Description
Original	31 December 1987			

National Technical Systems

SIGNATURES

Written by ______ Date 13 January 1988
Peter W. Pettoni, Technical Writer

Approved by ______ Date 1-13-1988
William J. Ison, Environmental Laboratory Manager

Reviewed by ______ Date 13 January 1988
Peter W. Pettoni, Quality Control Manager

National Technical Systems

TABLE OF CONTENTS

1.0 PURPOSE

1.1 The purpose of this report is to present the test procedures used and the results obtained during the performance of a reliability test program conducted to determine the conformance of Automated Integrated Survey Instruments (AISI's) to the requirements specified in the references in paragraph 2.0.

2.0 REFERENCES

2.1 Radian, Inc. Purchase Order Number 01937.

2.2 Operational/Environmental/Suitability Test Plan for Automated Integrated Surveying Instrument (AISI).

3.0 TEST ITEMS

One (1) Geodimeter, System 440 S/N 69417, and one (1) Theodolite, Wild T-2000, S/N FNR 314109 (both with accessory equipment), were received for testing.

4.0 SUMMARY

One (1) System 440 Geodimeter, and one (1) Wild T-2000 Theodolite were subjected to a seven-day Electronic Cycling (Reliability) test in accordance with Test XXXV of reference 2.2.

There was no damage noted to the units as a result of testing.

Testing was performed during the period December 3-11, 1987.

Refer to NTS Test Report 555-2134, dated 5 November 1987, for previous environmental testing.

5.0 TEST CONDITIONS AND TEST EQUIPMENT

5.1 <u>Test Conditions</u>

Unless otherwise specified herein, testing was performed at room ambient conditions defined as a temperature of 73 ±18°F (23 ±10°C), a relative humidity of 50 +40, -30 percent, and a barometric presure of 28.5 +2.0, -3.0 inches of mercury absolute (725 +50, -75 mm Hg).

5.2 Test Equipment

An itemized list of the test equipment used is included in Appendix A of this report. This equipment is calibrated, as required, in accordance with MIL-S-45662 with Change Notice ', and calibration is traceable to the National Bureau of Standards. Calibration records are maintained on file at NTS/Hartwood.

6.0 TEST DESCRIPTIONS AND RESULTS

Electronic Cycling (Reliability)

The Geodimeter and Theodolite were subjected to Electronic Cycling Testing in accordance with Test XXXV of reference 2.2.

The energized test items were placed in an environmental chamber at 55°F (13°C). At 7.5 hours into the seven-day soak, the Radian representative indicated the Wild T-2000 was not functioning properly. The Radian representative performed corrective measures, and indicated that both units were functioning properly.

The test items were subjected to a seven-day, 55°F (13°C) soak. During this period the items were turned on and the buttons noted in TABLE I were pressed. This configuration permitted the items to perform automated readings for approximately 9 minutes. Then each item was turned off for a period of 30 seconds. The period of time to press the buttons per TABLE I; the 9 minutes of automated readings; and the 30 seconds off period made a 10-minute cycle. This ten minute cycle was repeated over and over 24 hours per day or the seven-day test duration.

At the end of the seven-day test, the items were removed from the chamber, visually inspected, and subjected to performance testing by the Radian representative.

Results - Electronic Cycling

There was no visual damage noted to the test items as a result of testing.

The Radian representative recorded and retained results of all functional operational testing.

AISI RELIABILITY FUNCTION PROCEDURE

The Geodimeter and Wild T-2000 were subjected to Electronic Cycling Testing as follows:

Cycling

Step 1: Turned the units on

Step 2: Consecutive Functions

Geodimeter	Wild T-2000
Pressed F	Pressed Set
Pressed 22	Pressed Mode
Pressed Enter	Pressed 9
Pressed 0	Pressed 5
Pressed Enter	Pressed Run
Pressed Enter	Pressed 1
Pressed Enter	Pressed Run
Pressed Enter	Pressed Rep
Pressed TRK	Pressed Dist

Step 3: Turned the units off.

Summary of Cycling

1. Turned the units on.
2. Press the buttons in the sequence in Step 2.
3. The units remained on for 9 minutes and 30 seconds.
4. Turned unit off
5. The units remained off for 30 seconds.
6. Total cycle time was 10 minutes.

TABLE I

National Technical Systems

APPENDIX A

Test Equipment List

NTS

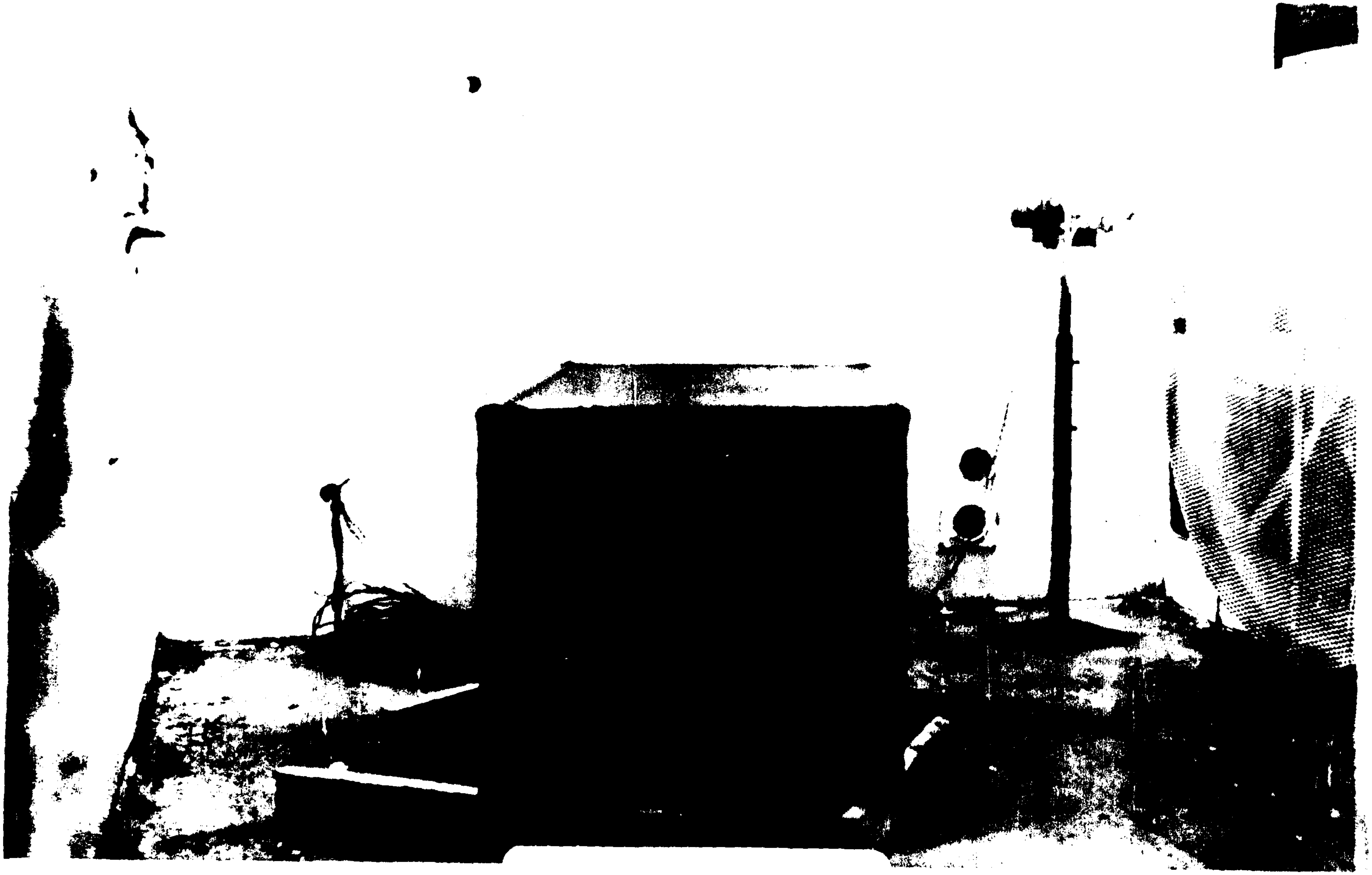
NTS Number	ENV 6300 D
Instrument	Chamber
Manufacturer	Tenney
Model Number	5X8X8 STR-85185
Serial Number	2114
Calibration Period	Used with calibrated equipment
Range and Accuracy	-100 - +200°F; N/A

NTS Number	E 6076 D
Instrument	Recorder
Manufacturer	Gould
Model Number	11015-4328-10
Serial Number	00623
Calibration Period	6 mo. (Cal. due 12 May 1988)
Range and Accuracy	0 to 1V; 0.15% span

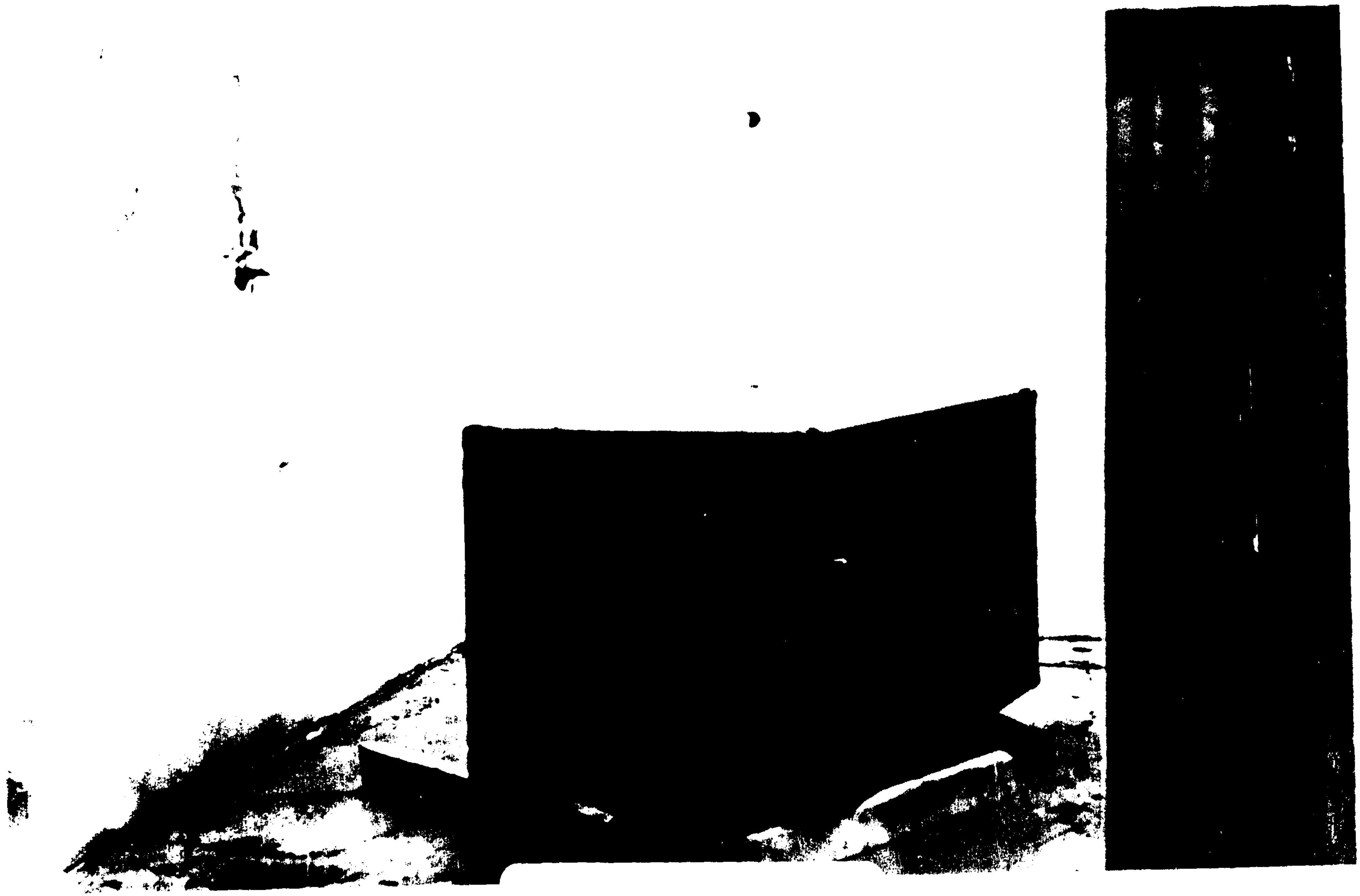
NTS Number	E 6103 D
Instrument	Module, Plug-in
Manufacturer	Gould
Model Number	12-4715-09
Serial Number	00842
Calibration Period	6 mo. (Cal. due 12 May 1988)
Range and Accuracy	1mV to 100 VDC span; 0.1% span

APPENDIX C

Photographs

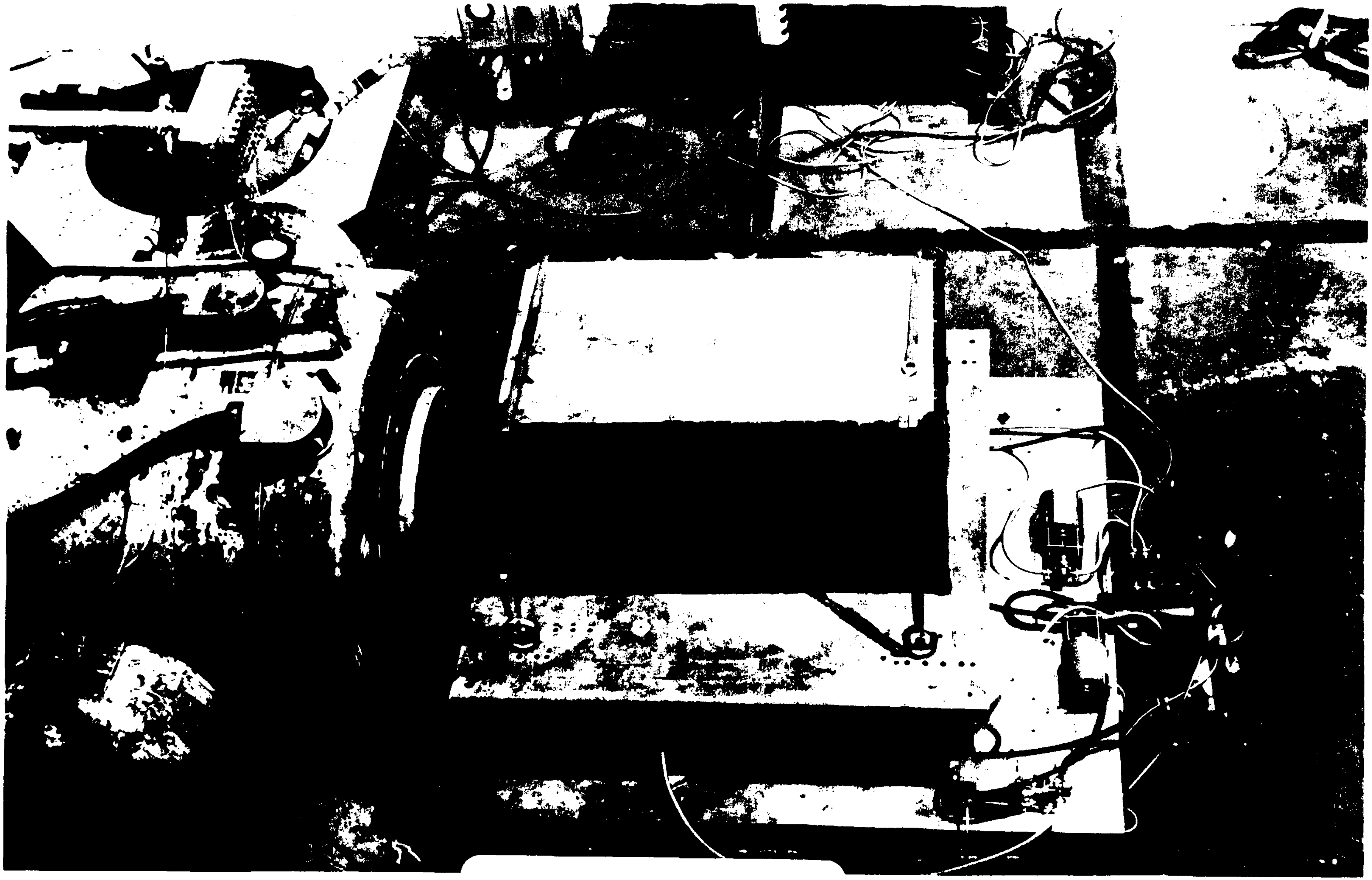


High Temperature



Low Temperature

Sand and Dust



Vibration

National Technical Systems

ENVIRONMENTAL TESTING
OF A TRANSPORTATION TRUNK

Report No. 555-2174
P. O. No. 01938
Date 13 November 1987

National Technical Systems

ENVIRONMENTAL TESTING
OF A TRANSPORTATION TRUNK

PREPARED FOR: RADIAN, INC.
5845 Richmond Highway
Alexandria, VA 22303

PREPARED BY: NATIONAL TECHNICAL SYSTEMS
DC Division
State Route 748
Hartwood, VA 22471

Report No. 555-2174
P. O. No. 01938
Date 13 November 1987

National Technical Systems

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Rev No.	Date	Page No.	Para No.	Description
Original	13 Nov 87	-	-	-

National Technical Systems

Report No. 555-2174
P. O. No. 01938
Date 13 November 1987

SIGNATURES

Written by Peter W Pettoni Date 24 November 1987
Peter W. Pettoni, Technical Writer

Approved by William J. Ison Date 11-24-87
William J. Ison, Environmental Laboratory Mgr.

Reviewed by P.W. Pettoni Date 24 November 1987
Peter W. Pettoni, Quality Control Manager

National Technical Systems

Report No. 555-2174
P. O. No. 01938
Date 13 November 1987

TABLE OF CONTENTS

Report No. 555-2174
P. O. No. 01938
Date 13 November 1987

National Technical Systems

1.0 PURPOSE

1.1 The purpose of this report is to present the test procedures used and the results obtained during the performance of an environmental test program conducted to determine the conformance of a Transportation Trunk to the requirements specified in the references in paragraph 2.0

2.0 REFERENCES

2.1 Radian, Inc. Purchase Order Number 01938

2.2 Operational/Environmental/Suitability Test Plan for Automated Integrated Surveying Instrument (AISI).

3.0 TEST ITEM

One (1) Transportation Trunk (without part number) S/N 1654, was received for testing.

4.0 SUMMARY

The Transportation Trunk was subjected to High Temperature Storage, High Temperature Operation, Low Temperature operation/storage, Rain, Sand and Dust, and Vibration testing in accordance with the requirements of the references in paragraph 2.2.

The closed Transportation Trunk was received at NTS and was subjected to the complete test program without being opened. All examinations were external only. The Transportation Trunk was returned to the customer upon completion of the test program in the closed condition per customer's request.

There was no external damage noted to test item as a result of testing.

5.0 TEST CONDITIONS AND TEST EQUIPMENT

5.1 Test Conditions

Unless otherwise specified herein, testing was performed at room ambient conditions defined as a temperature of 73 $\pm$18°F (23 $\pm$10°C), a relative humidity of 50 +40, - 30 percent, and a barometric pressure of 28.5 +2.0, -3.0 inches of mercury absolute (725 +50, -75 mm Hg).

National Technical Systems

5.2 Test Equipment

An itemized list of the test equipment is included in Appendix A of this report. This equipment is calibrated, as required, in accordance with MIL-S-45662 with Change Notice 1, and calibration is traceable to the National Bureau of Standards. Calibration records are maintained on file at NTS/Hartwood.

6.0 TEST DESCRIPTIONS AND RESULTS

6.1 High-Temperature Storage

The trunk was subjected to High-Temperature Storage testing in accordance with Procedure VIII of reference 2.2. The nonoperating test item was placed in a chamber at ambient temperature. The chamber internal temperature was then raised in 1 hour to 71°C (160°F), and the item was soaked for 4 hours. The chamber temperature was then reduced to ambient in 1 hour and 45 minutes after which the test item was removed from the chamber and subjected to an external visual examination.

Results - High-Temperature Storage

There was no external visual damage noted to the trunk.

The Radian representative requested that the trunk remain closed during and after the testing.

Refer to Appendix B for recorded temperature plots, and Appendix C for Photographs.

6.2 High-Temperature Operation

The trunk was subjected to High-Temperature Operation testing in accordance with Procedure VII of reference 2.2.

The test item was placed in an environmental chamber at ambient temperature. The chamber internal temperature was then raised to 120°F (49°C) in 90 minutes, and the test item was soaked for 4 hours. After the 4-hour soak at 120°F (49°C), the chamber internal temperature was reduced to ambient in 2 hours and 30 minutes.

At the conclusion of testing, the test item was removed from the chamber and subjected to an external visual examination.

Results - High-Temperature Storage

There was no external visual damage noted to the trunk as a result of testing.

The Radian representative requested that the trunk not be opened.

Refer to Appendices B and C for temperature plots and photographs of the test setup.

6.3 Low Temperature Operation/Storage

Low-Temperature Storage

The trunk was subjected to Low-Temperature Operation/Storage testing in accordance with Procedure XV of reference 2.2.

OPERATION

The test item was placed into an environmental chamber. The chamber temperature was then reduced to -5°F (-21°C) in 3 hours and 30 minutes, and the test item was soaked for 4 hours.

STORAGE

At the end of the 4-hour, -5°F (-21°C) soak, the chamber temperature was reduced to -50°F (-45.5°C) in 1 hour and 45 minutes, and the test item was soaked for 6 hours. At the end of the 6-hour soak at -50°F (-45.5°C), the chamber temperature was returned to ambient, and the test item was soaked for 24 hours. At the end of the 24-hour ambient soak, the test item was removed from the chamber and subjected to an external visual examination.

Results - Low-Temperature Operation/Storage

There was no external visual damage noted to the test item.

The Radian representative requested that the test item remained closed.

Refer to Appendix B for plots of chamber temperature, and Appendix C for photographs.

National Technical Systems

6.4 Rain

The trunk was subjected to Rain testing in accordance with Procedure XVII of reference 2.2.

The test item was placed into a chamber preconditioned to 68°F (20°C) and soaked for 30 minutes. The item was then removed from the chamber and placed in the rain test setup.

The rain test was begun by exposing one side of the item to 30 minutes of wind-driven rain at 40 miles per hour and rainfall rate of 4 inches/hour. The rainfall was then stopped. The remaining three sides were the consecutively exposed to 30 minutes of rainfall each. After rain exposure to all four sides, the item was wiped down and subjected to an external visual examination.

Results - Rain

There was no external damage noted to the test item as a result of testing.

The Radian representative requested that the trunk remain closed.

Refer to Appendix C for photographs of the test setup.

6.5 Sand and Dust

The trunk was subjected to Sand and Dust testing in accordance with Procedure XXX of reference 2.2.

The test item was placed into the sand and dust chamber. The chamber temperature was increased to 23°C (74°F) with the relative humidity maintained at less than 28%, and the air velocity maintained at 320 feet per minute. Once these conditions were obtained, the dust feeder was turned on, blowing dust onto the test item at a rate of 0.3 $\pm$0.2 grams per cubic foot. These conditions were maintained for 15 minutes. All chamber controls were then turned off, and the test item was allowed to return to ambient conditions. The accumulated dust was brushed off and the test item was removed from the chamber and subjected to an external visual examination.

National Technical Systems

Results - Sand and Dust

There was no external visual damage to the tested item.

The Radian representative requested that the trunk remain closed.

Refer to Appendix C for photographs of the setup.

6.6 Vibration

The trunk was subjected to Vibration testing in accordance with Procedure XX of reference 2.2.

The test item was rigidly secured to an electro-dynamic vibration exciter and exposed to vibrational cycling in each of three mutually perpendicular axes at the following frequencies and levels.

7-200 @ 1.5 g's peak
One cycle (7-200-7 Hz @ 5 minutes/cycle) per axis

At the completion of each vibration cycle, the item was subjected to an external visual examination.

Results - Vibration

There was no external visual damage noted to the test item.

The Radian representative requested that the test item remain closed.

Refer to Appendices B and C for vibration plots and photographs of the test setup.

APPENDIX A

Test Equipment List

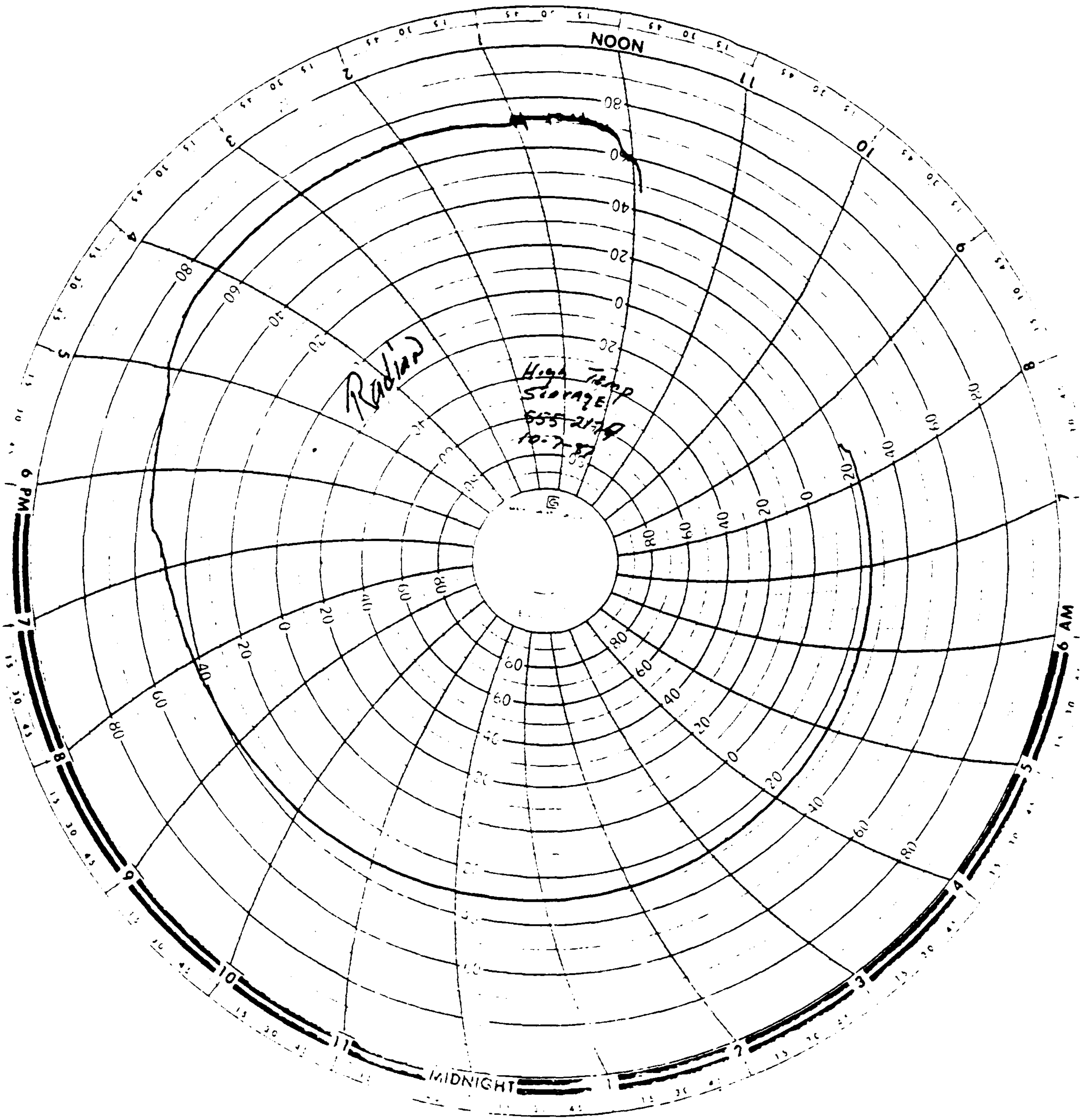
National Technical Systems

TEST EQUIPMENT LIST

	Instrument	Manufacturer	NTS Id No.	Cal Date	Cal Due
Rain					
	Aneometer	Mesa	ENV6053D	8-6-87	8-6-88
	Raingage	Springfield	ENV6039D	2-14-87	2-14-88
Temperature					
	Controller	Honeywell	ENV6011D	9-22-87	3-22-88
	Chamber	Standard	ENV6322D	used with calibrated equipment	
Dust					
	Probe	Hygrodynamics	ENV6052D	4-7-87	10-7-87
	Controller	Honeywell	ENV6022D	5-18-87	11-18-87
Vibration					
	Accelerometer	PCB	D6074D	5-28-87	11-28-87
	Signal Conditioner	PCB	D6093D	6-5-87	12-5-87
	Vibration Controller	Hewlett-Packard	D6054D	6-8-87	6-8-88
	Vibration Exciter (C-220)	MB	used with calibrated equipment		

APPENDIX B

Temperature & Vibration Plots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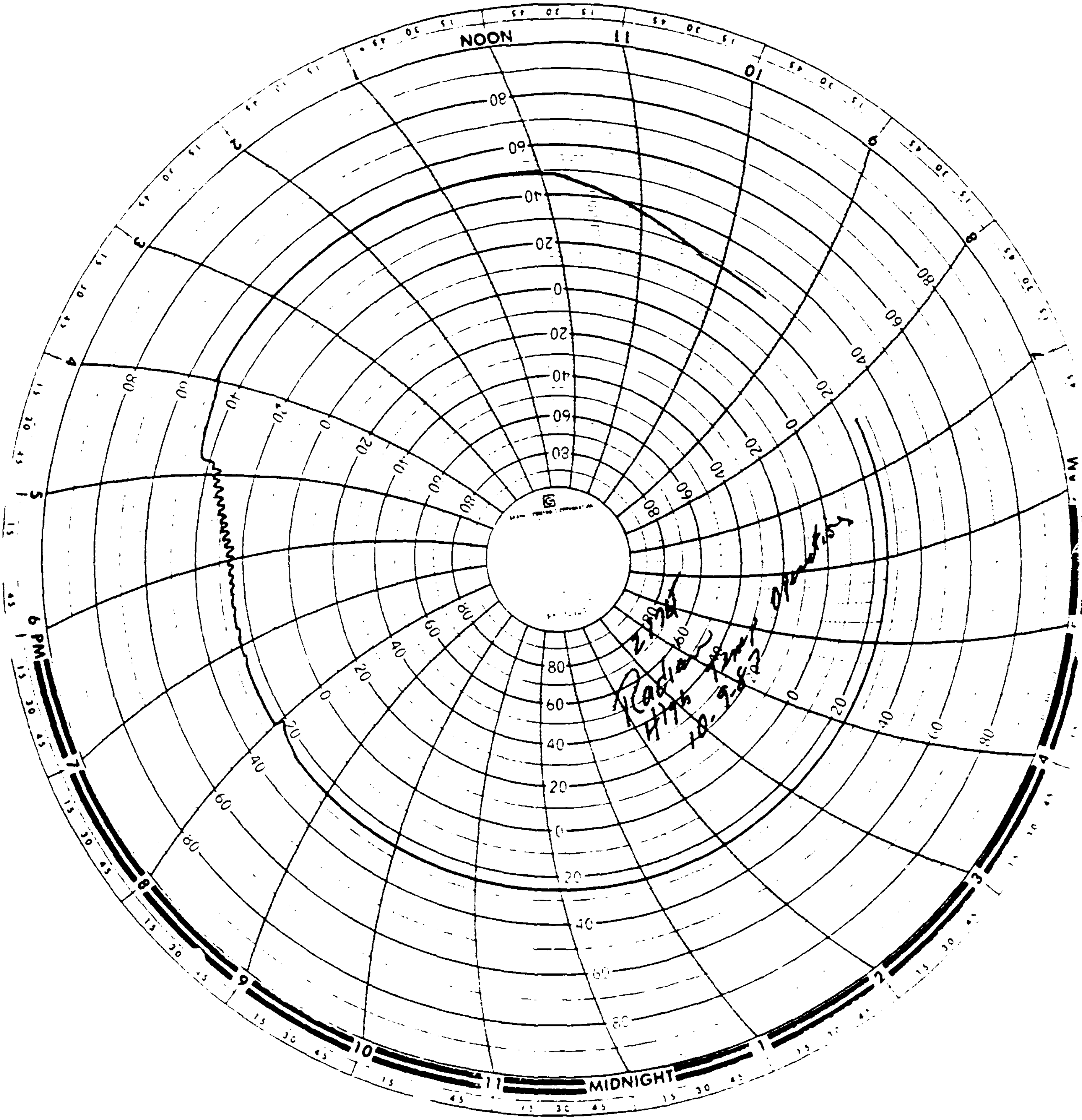
MIDNIGHT
6 PM
6 AM
Radiad
High Temp
Storage
10-7-87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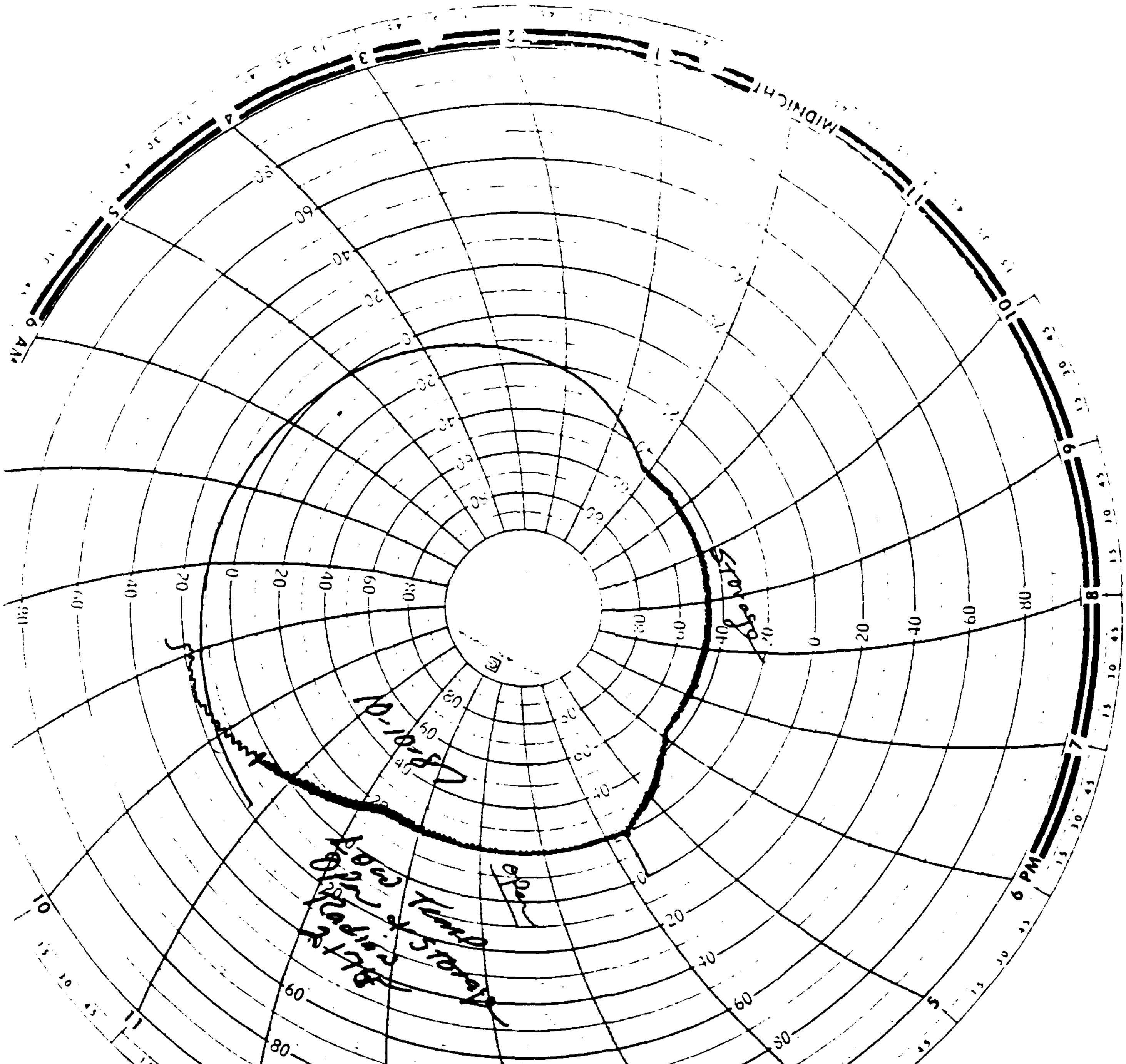
MIDNIGHT
6 PM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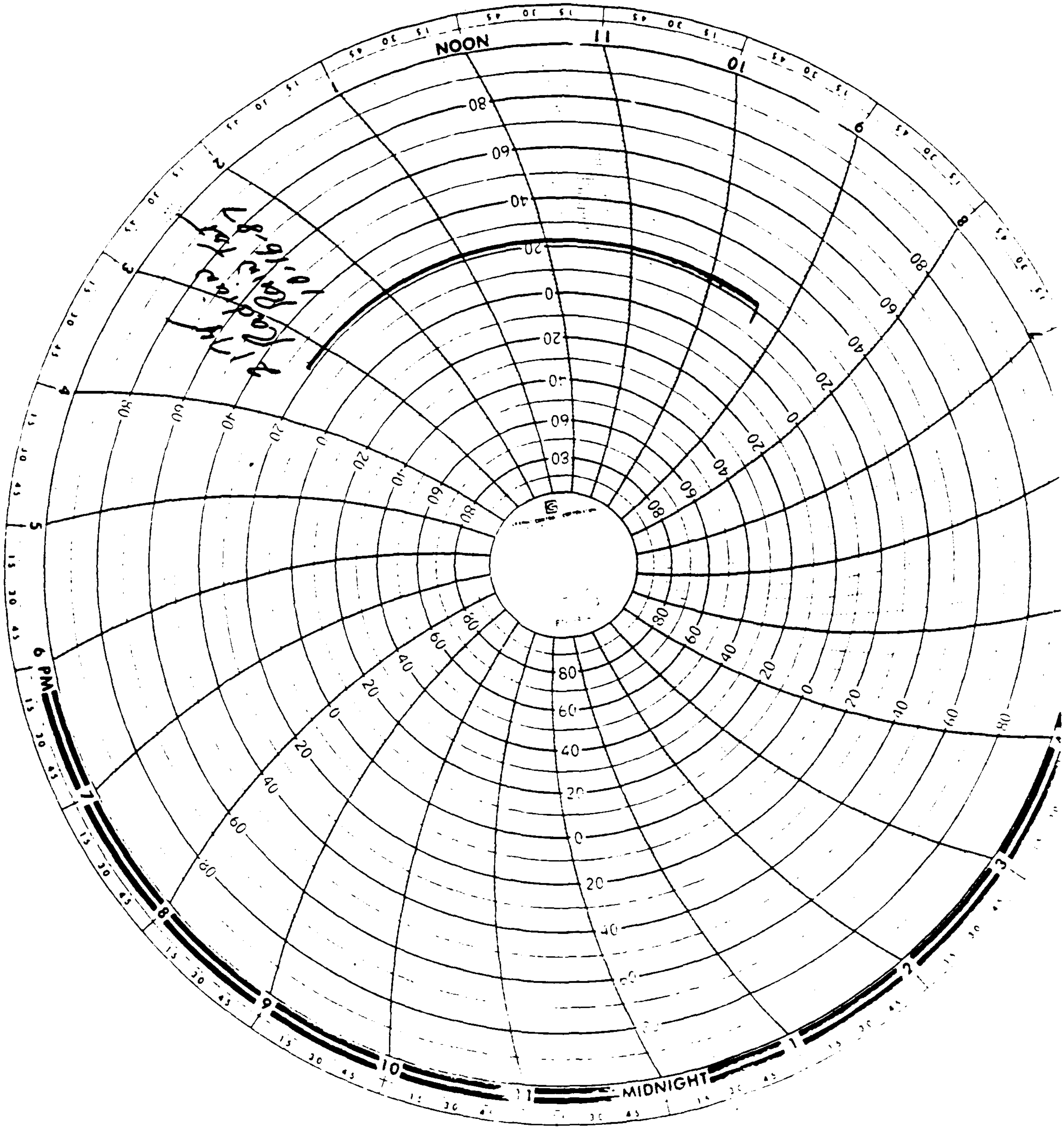
NOON
6 AM
Storage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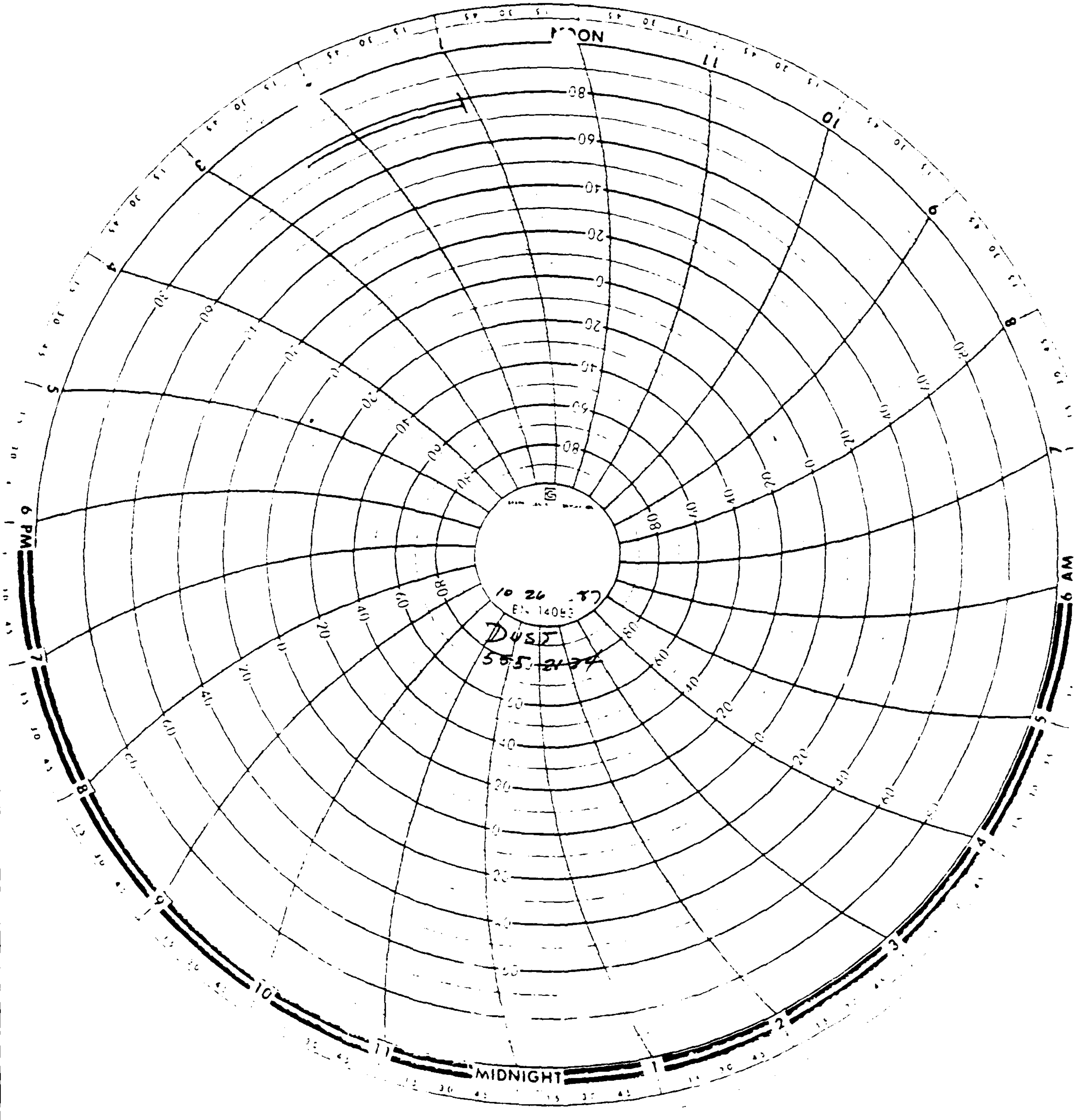
MIDNIGHT
PM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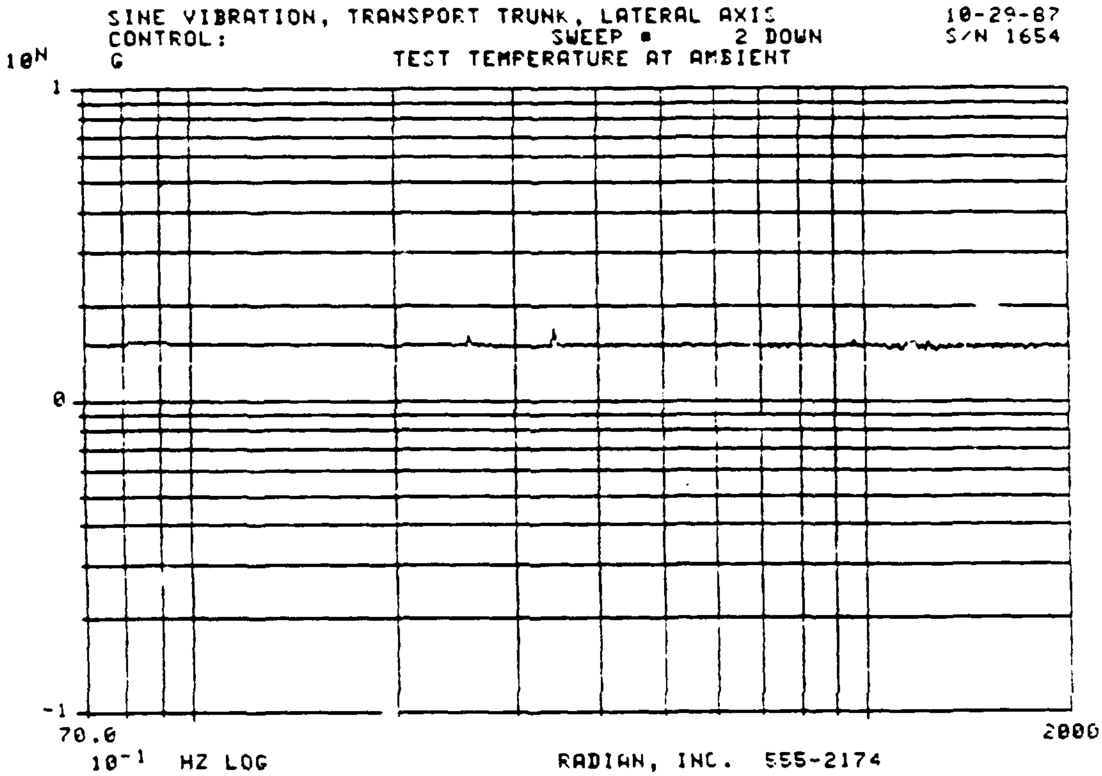
MIDNIGHT
6 PM
6 AM
DUST


SINE VIBRATION, TRANSPORT TRUNK, LATERAL AXIS
10-29-87
CONTROL:
SWEEP # 2 DOWN
S/N 1654
10N
G
TEST TEMPERATURE AT AMBIENT
1
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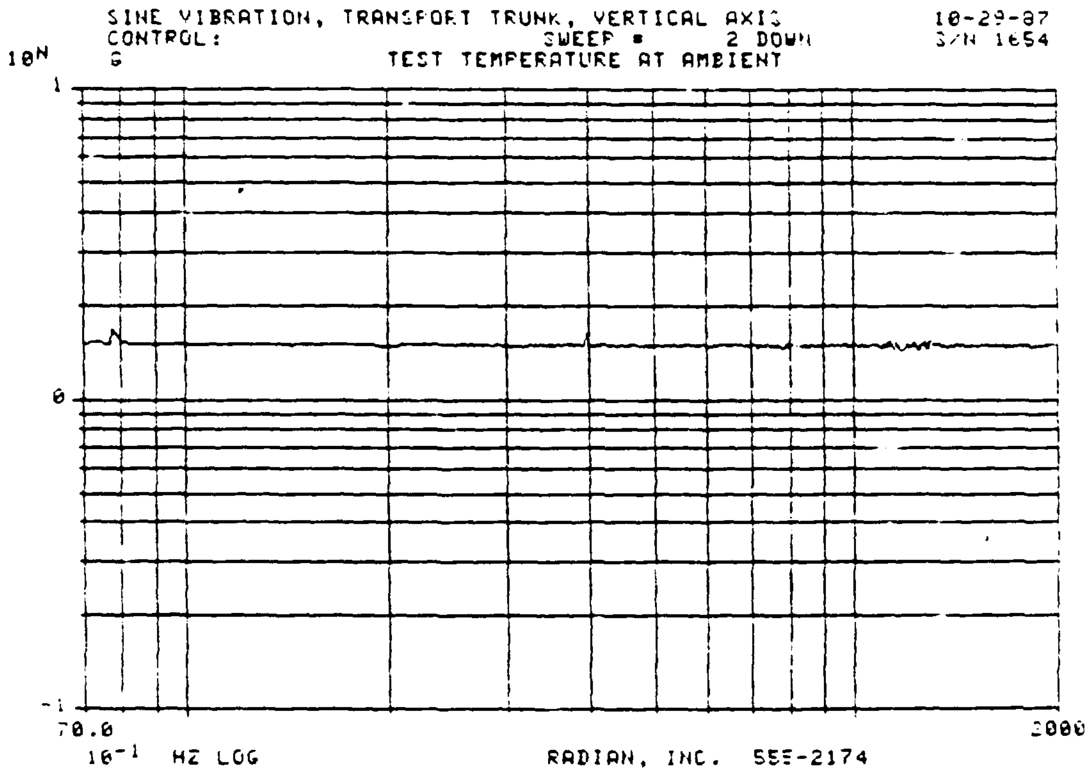
-1
70.0
2000
10-1 HZ LOG
RADIAN, INC. 555-2174


SINE VIBRATION, TRANSPORT TRUNK, VERTICAL AXIS
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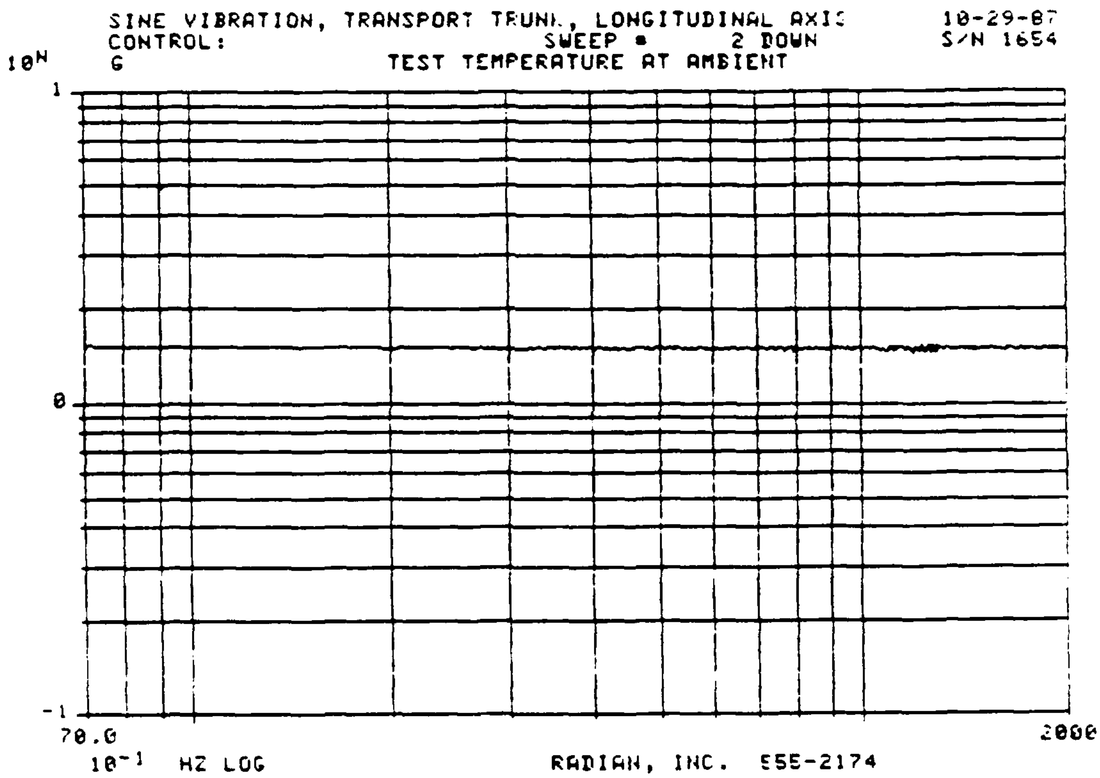
RADIAN, INC. 555-2174


SINE VIBRATION, TRANSPORT TRUNK, LONGITUDINAL AXIS
10-29-87
CONTROL:
SWEEP = 2 DOWN
S/N 1654
10^N
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TEST TEMPERATURE AT AMBIENT
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70.0
2000
10^{-1}
HZ LOG
RADIAN, INC. 55E-2174

TRADOC ACN 07375[illegible]

U.S. ARMY ENGINEER SCHOOL

DIRECTORATE OF COMBAT DEVELOPMENTS

FORT BELVOIR, VIRGINIA 22060-5281

INDEPENDENT EVALUATION PLAN (IEP)

for the

AUTOMATIC INTEGRATED SURVEY INSTRUMENT (AISI)

through

PRODUCTION AND DEPLOYMENT

by

Ralph A. Redmond

August 1987

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1.0 INTRODUCTION AND BACKGROUND:

1.1 Purpose: This Independent Evaluation Plan (IEP) has been prepared to support the acquisition of an Automatic Integrated Survey Instrument (AISI) through a Non-Developmental Item (NDI) approach. This IEP is developed in accordance with the provisions of AR 70-1, TRADOC Reg 71-9, and TRADOC Pam 71-13. It will provide the following: user issues and criteria for Market Investigation and subsequent testing and evaluation, input on integrated testing and evaluation for the Test and Evaluation Master Plan (TEMP), methodology and analytical techniques to be used by the evaluator for analysis of data collected, and the basis for preparation of the Independent Evaluation Report (IER) for the Milestone I/III decision in-process review.

1.2 Scope: This evaluation plan has been designed to address the complete range of user concerns by identifying issues and criteria associated with determining the military suitability and logistical supportability, RAM, training, and MANPRINT of an Automatic Integrated Survey Instrument (AISI). The evaluation will use relevant data from all testing and assessments conducted.

1.3 Need: On the AirLand Battlefield, survey elements must rapidly collect, process, and assess survey data. The U.S. Army Engineer School Combat Support, Engineering, and Mine Warfare Mission Area Analysis (CSEMW MAA), May 83, identified deficiencies in the projected ability of topographic survey and construction survey elements to fulfill this requirement.

1.4 Justification: The primary operational deficiency concerning topographic and construction survey is lack of speed. Survey equipment currently in use requires all raw data to be collected and recorded manually. This process is very time consuming and is prone to errors. The current equipment causes survey requirements to take weeks and months to obtain the necessary accuracy but the requirements are for completion times of hours and days.

1.5 Program History: The requirement for an AISI was identified in the Topographic Support System (TSS) Required Operational Capability (ROC), in 1978. At that time, further procurement was not pursued due to high cost and only one source for procurement. The Operational and Organizational (O&O) Plan for AISI received TRADOC approval on 15 Oct 86. This O&O Plan further identified and quantified the requirements for the AISI. Current plan is to use a non-developmental item (NDI) acquisition strategy for AISI, if systems are commercially available with performance characteristics to satisfy user needs. Indication is that such systems are available and the plan is to authenticate the approved TSS ROC as the requirements document for AISI and to incorporate the full spectrum of AISI characteristics and requirements into that document.

1.6 System Description: The AISI will consist of the following components or subsystems:

a. An automatic, electronic, digital theodolite/distance meter, with data displays.

b. Reflective devices necessary to perform measuring functions.

c. Tripod(s) and pole(s) to support measuring instrument and reflective devices.

d. Electronic data recorder.

e. Appropriate ruggedized carrying cases.

f. Necessary portable (battery) power supplies.

The AISI will be operated by a three person crew. The crew will be able to backpack the AISI in an operational environment when necessary.

1.7 Concept of Employment: The AISI integrates the capabilities of currently deployed direction and distance measuring devices with microcomputer technology. It will be employed by topographic and construction survey elements.

a. TOPOGRAPHIC SURVEY. Topographic survey units will use the AISI to automate conventional survey activities. Conventional survey is used to provide position data in support of weapon systems, communications, intelligence gathering, and command and control activities. These surveys are conducted in direct support of division artillery, corps units, and in general support to echelons above corps (EAC). The AISI will significantly increase the speed and accuracy of topographic survey operations which are conducted in the following phases:

(1) Prebattle: Predeployment of survey units to various areas of interest in the prebattle phases ensures that adequate position data and densification of position data exists. The AISI is used to establish and upgrade primary control in these areas allowing supported units to have a reliable, properly densified control data base to initiate operations.

(2) Battle: Efforts will continue toward satisfying requirements not met during the prebattle period together with those expedient, situation-oriented requirements generated by combat operations. The rapid response time of the AISI will allow the topographic survey team to respond to supported unit requirements, except for those that are affected by opposing force interdiction.

(3) Postbattle: Topographic survey response will be redirected to support the reestablishment of network geodetic control. Using this network, and in conjunction with construction survey, topographic survey teams respond

to supported unit requirements, except for those that are affected by opposing force interdiction.

(4) Interface with Other Systems: The AISI will use the Doppler Satelite Survey System and Global Positioning System for extension of prime control established with these systems. It will be used for alignment and updating position data of the Position and Azimuth Determining System and other Inertial Navigation Systems. The microprocessor will allow direct access to the Defense Mapping Agency's Airfield Geodetic Data File and Data Conversion data base allowing for rapid dissemination of the information contained in them.

b. CONSTRUCTION SURVEY. Construction survey units will use the AISI to perform construction support surveys such as airfiel, heliport, road and port and bridge construction as well as major facility layout. These construction projects are performed in support of division, corps, and EAC activities. The AISI will significantly improve the response time of construction survey elements which are conducted in the following phases:

(1) Prebattle: Construction survey elements are employed with combat heavy battalions involved in the preparation of various areas of interest. This involvement includes construction of airfields, heliports, roads, bridges and ports, and facilities to be utilized by friendly forces in the event of conflict.

(2) Battle: Efforts will continue toward satisfying the requirement not met during the prebattle period. The rapid response time of the AISI will allow survey support for construction to continue on a more accurate, time-efficient scale.

(3) Postbattle: Construction survey responses will be redirected to

support the reestablishment of basic facilities, roads, bridges, and airfields of the local affected area.

(4) Interface with Other Systems: The construction support provided by the AISI will ensure the maintenance and usability of airfields, bridges and roads. This will have a direct impact on all aircraft/vehicular systems utilizing these facilities.

1.8 Basis of Issue: The AISI, along with associated data reduction equipment, will be issued to each survey squad organic to the Engineer Topographic Battalion (TA), 05605L000 HHC, Topographic Engineer Company, 05606L000, Survey Squad 05-540LB, and each survey element of the Construction Battalion TOE 05-116H. The peripherals required for computation, plotting, and printing of data will be issued as required by BOIP (one for each 17-man topo team and one per construction battalion). The topographic survey squad is direct support (DS) to corps and general support (GS) at EAC.

1.9 Combat Developer Project Officer: Mr. Harold Hester, Materiel & Logistics System Division, Directorate of Combat Developments, ATZA-CDM, U.S. Army Engineer School, Fort Belvoir, VA 22060-5281, AUTOVON 354-5976/2489.

1.10 Independent Evaluator: Mr. Ralph Redmond, Test and Evaluation Division, Directorate of Combat Developments, ATZA-CDT, U.S. Army Engineer School, Fort Belvoir, VA 22060-5281, AUTOVON 354-3777/3346.

SECTION II

2.0 Operational Issues and Criteria for the Automatic Integrated Survey Instrument (AISI):

2.1 Critical Evaluation Issues and Criteria:

2.1.1 Issue: Does the AISI effectively perform topographic and construction survey tasks in an operational environment?

2.1.1.1 Scope: This issue will evaluate the capability of the candidate(s) to effectively perform topographic and construction survey tasks when employed by representative users IAW the operational mode summary/mission profile (OMS/MP). An assessment will be made of each candidate's demonstrated performance in climatic design types hot, basic, and cold, IAW AR 70-38. Testing will be conducted IAW the OMS/MP and test settings described in the test support package (TSP). Testing will be conducted in ambient weather conditions, during day and night/limited visibility conditions expected on the battlefield. Data collected will include the time required to complete tasks and the ease with which operator's performed required tasks. Data gathered will be used in a baseline comparison with current survey equipment.

2.1.1.2 Criteria:

2.1.1.2.1 The assigned crew using the AISI will perform the following tasks within the time and accuracy constraints specified 95% of the time.

AISI TASK LIST

TASK		ACCURACY	TIME
1. Preparation for movement		N/A	15 min
2. Preparation for field operations (setup)			
a. Distance Measurement		N/A	5 min
b. Direction Measurement (horiz & vert)		N/A	8 min
3. Conduct data collection			
a. Distances		+/-5mm + 3ppm	2 min
b. Directions (horiz & vert)	(Topo)	+/-1 sec	10 min
	(Const)	+/-30 sec	5 min
c. Layout curves (per point)		+/-.0242ft per 1000ft	1 min
d. Planetabling (per point)		+/-.0242ft per 1000ft	1 min
4. Process field data	(Topo)	position closure ≤ 1:20,000	3-5 min**
	(Const)	position closure ≤ 1: 5,000	3-5 min**

** Dependent upon number of stations in traverse scheme.

2.1.1.2.2 The AISI must be capable of operating, IAW the OMS/MP, on an ~~internal rechargeable~~ battery for ~~up to~~ 12 hours. It must also be capable of operating on an external 12 to ~~24~~ volt DC vehicular battery.

2.1.1.3 Rationale: The AISI must be able to measure deflections and distances accurately and in a timely manner if it is to provide required support to combat units. It must also be capable of operating for an extended period on battery power to satisfy the OMS/MP.

2.1.1.4 Source: O&O Plan.

2.1.2 Issue: Does the AISI provide adequate data transfer capability?

2.1.2.1 Scope: This issue will evaluate the capability of the candidate(s) to directly record measured data to their component data recorder when employed by representative users IAW the OMS/MP. This issue will also evaluate the capability to "dump" or transfer electronic data via a RS232/V24 interface to an external microprocessor. Additionally, information concerning the ability of representative users to transfer data from the microcomputer to the data recorder and use that data to perform survey layouts will also be collected.

2.1.2.2 Criteria:

2.1.2.2.1 The AISI, when employed by representative users will be able to record data to the data collector and transfer that data to the external microprocessor with 98% fidelity, 95% of the time.

2.1.2.2.2 Representative users will be able to transfer data from the external microprocessor to the data recorder and with that data, use the AISI to layout precomputed distances and deflection with 98% fidelity, 95% of the time.

2.1.2.3 Rationale: The AISI must have the capability for electronic data collection, transfer, and use if it is to provide required support to combat units.

2.1.2.4 Source: O&O Plan.

2.2 Non-Critical Evaluation Issue and Criteria:

2.2.1 Issue: Does the AISI demonstrate adequate RAM for operational mission requirements?

2.2.1.1 Scope: Data will be collected to determine the demonstrated RAM characteristics of each candidate and to identify potential availability and maintainability problems. Operational RAM characteristics will be evaluated as the system is exposed to a variety of environmental conditions while conducting operational missions IAW the OMS/MP. Reliability, maintainability, and logistic support data will be collected and analyzed, and the impact on system readiness objectives and/or operational availability (A_o) assessed. Maintenance data will include level of maintenance required and effectiveness of diagnostic procedures. Skills and manhours to accomplish the required maintenance tasks will be evaluated. Operational reliability in terms of mean time between operational mission failures will be scored using the failure definition/scoring criteria (FD/SC) (Appendix D), developed jointly by the combat developer, materiel developer, and independent evaluators (both technical and operational).

2.2.1.2 Criteria:

2.2.1.2.1 MTBOMF (C) for the AISI must equal or exceed ~~TBD~~ 120 hours.

2.2.1.2.2 The maintenance ratio for the AISI will not exceed ~~TBD~~ 0.014 maintenance manhours/hours of operation.

2.2.1.2.3 A_o for the AISI will be ~~TBD~~ .85 or greater.

~~(NOTE: RAM parameters will be furnished by USAES upon the approval of the RAM rationale.)~~

2.2.1.3 Rationale: Quantification of AISI RAM characteristics is needed to establish maintenance burden and to ensure that AISI availability is adequate to support mission requirements.

2.2.1.4 Source: USAES; User requirements.

2.2.2 Issue: Are there any electronic compatibility problems associated with operation of AISI?

2.2.2.1 Scope: Data will be collected to determine the electronic characteristics of each candidate and to identify potential interference problems between the AISI and other electronic equipment projected for use in the same area. During testing, any incident of interference will be reported and analyzed to evaluate its impact on operation of AISI or other systems.

2.2.2.2 Criterion: The AISI shall not present any interference to other systems nor be susceptible to interference from other systems used in the same area of the battlefield.

2.2.2.3 Rationale: To operate effectively, the AISI should not encounter electronic interference from other equipment operated on the battlefield. Likewise, the AISI should not present interference to other friendly systems.

2.2.2.4 Source: USAOTEA; User requirement.

2.2.3 Issue: Is the technical documentation for AISI accurate, comprehensive, and effective?

2.2.3.1 Scope: During testing, test players will be observed, while performing operator, maintainer, and supervisor tasks using commercial manuals. Accuracy, comprehensiveness, and effectiveness will be assessed. Comments will be provided in the following areas:

a. Portions of text that are not clear, comprehensive, concise, or accurate.

b. Portions of text that operators, maintainers, and supervisors cannot adequately use or that are unnecessary or inadequate.

2.2.3.2 Criteria:

2.2.3.2.1 The AISI technical documentation and other software must correctly describe each of the critical task requirements.

2.2.3.2.2 Ninety-five percent of trained representative military users, using the technical documentation, will be able to perform 100% of the critical tasks.

2.2.3.2.3 The Reading Grade Level (RGL) of all technical documentation and training manuals will be within ± one RGL for the particular MOS designated to operate/maintain the system.

2.2.3.3 Rationale: Manuals and other documentation must be adequate for use with the AISI.

2.2.3.4 Source: USAES; User requirements.

2.2.4 Issue: Does the training program adequately prepare the representative soldier to use and maintain the AISI in an operational environment?

2.2.4.1 Scope: The evaluation of training support will be conducted during all phases of testing. The intent of the evaluation is to assess the training as outlined in the Individual and Collective Training Plan (ICTP), and as represented by the Training Test Support Package (TTSP), to train representative soldiers to establish performance standards. Pretest (pretraining) skills will be used as the baseline for assessing training effectiveness by a comparison to posttest skills. Sources of tasks, conditions and standards identified in the ICTP will be used as the basis for the training evaluation. The entire training package will be assessed and trainer and tester input will be solicited to determine adequacy of training devices, manuals, aids, and other material. Training aids or devices will be evaluated for their effectiveness and ability to influence training transfer. Individual performance will be assessed during normal conduct of the test. Tasks that players have particular difficulty with will be reported and the training program for those tasks, including the performance standards, will be reassessed. Tasks necessary for operation and maintenance that were omitted from the training plan will be reported.

2.2.4.2 Criterion: Upon completion of training, 95% of the representative soldiers will be able to perform all of the critical tasks identified in the TTSP to prescribed standards.

2.2.4.3 Rationale: The training program must prepare the soldier to use and maintain the system.

2.2.4.4 Source: O&O Plan.

2.2.5 Issue: Is AISI designed for efficient and effective logistics support?

2.2.5.1 Scope: This issue is designed to assess the commercial end items for their logistical support requirements. Areas of consideration are packaging, handling and storage, facilities, supply/provisioning, standardization and interoperability. Effects of modularity on logistics and training will be assessed. Also, the logistical support hardware and software requirements for the system will be assessed. The adequacy and military availability of common and special tools, supporting test equipment, repair parts and maintenance facility requirements will be determined. Software elements assessed shall include technical manuals, repair parts and special tool list (RPSTL), maintenance allocation chart (MAC) and parts allocation chart (PAC). Logistical considerations of supply will be determined by the Integrated Logistic Support (ILS) Manager based on the approved basis-of-issue plan and the Materiel Fielding Plan (MFP). The frequency and type of logistic-related test incidents will form the basis for subjectively assessing the adequacy of the logistic program.

2.2.5.2 Criteria:

2.2.5.2.1 Repair parts and warranties from the manufacturer will be specified and must support the system at all levels of maintenance.

2.2.5.2.2 The supply and maintenance organization will be completely described and the responsibility and work flow for each level of supply and maintenance will be clearly defined in the MAC.

2.2.5.2.3 Integrated logistical support responsibilities, including maintenance and supply will be allocated to the proper level consistent with existing supply and maintenance procedures as determined by TOE.

2.2.5.2.4 Requirements for supply and maintenance facilities will be consistent with current Army facilities, capabilities, and allocations.

2.2.5.3 Rationale: Logistic support plans and procedures must be validated to adequately evaluate the supportability of the AISI.

2.2.5.4 Source: O&O Plan.

2.2.6 Issue: Can the AISI be transported by all required modes?

2.2.6.1 Scope: This issue addresses the transportability characteristics of the AISI in assessing transport by various modes. Due to small size and weight, it is not anticipated that the AISI will have transportability limitations. However, the ability of the AISI to withstand the rigors of transport must be answered. Additionally, the ability of the crew to transport the AISI, by vehicle and backpack must be evaluated.

2.2.6.2 Criteria:

2.2.6.2.1 AISI will be transportable within the using units existing TOE transportation capability.

2.2.6.2.2 The assigned crew will be able to properly package the AISI for transport.

2.2.6.2.3 The ruggedized carrying case will protect the AISI from damage during normal transport.

2.2.6.2.4 The AISI will be man portable in its carrying case and be capable of being transported (backpacked) by the assigned crew.

2.2.6.3 Rationale: The AISI carrying case must provide protection adequate for worldwide transport. Additionally, the system must be man portable to fulfill its mission requirements.

2.2.6.4 Source: O&O Plan.

2.2.7 Issue: Are there any safety or health hazards associated with the AISI?

2.2.7.1 Scope: This issue will address candidate items for the purpose of identifying and assessing safety and health hazards during all phases of testing to include storage, transport, maintenance and operation. All safety and health hazard discrepancies identified must be recorded and categorized IAW MIL-STD 882B.

2.2.7.2 Criteria:

2.2.7.2.1 The AISI will not contain any uncontrollable safety or health hazards.

2.2.7.2.2 The AISI design will comply with applicable safety requirements IAW AR 385-10, 385-16, 40-5, 40-10, MIL-STD 454 and TB MED 524.

2.2.7.3 Rationale: The AISI must be designed to minimize safety hazards.

2.2.7.4 Source: O&O Plan.

2.2.8 Issue: Is the AISI adequately designed with regard to sound human factors engineering (HFE) principles?

2.2.8.1 Scope: This issue addresses the design of candidate(s) with regard to human factors engineering principles when the system is employed in an operational environment by representative users. A trained government human factors engineer will observe testing and prepare a HFE assessment report which will be provided to the independent evaluators for input to the independent evaluation report (IER). Testers will report HFE problems as they occur.

2.2.8.2 Criteria:

2.2.8.2.1 The AISI shall meet the human factors engineering requirements of AR 602-1 and MIL-H 46855.

2.2.8.2.2 Personnel must be able to transport set-up, operate, and store the AISI in its carrying case while wearing cold weather clothing.

2.2.8.3 Rationale: Design for human factors promotes effective mission performance.

2.2.8.4 Source: O&O Plan.

SECTION III

DENDRIDITIC DATA SOURCE MATRIX

OBJECTIVE/ISSUE/CRITERIA	DATA SOURCE				
	CT	STUDY	GT	OT	TT
2.1 Critical Evaluation Issues & Criteria					
2.1.1 Survey Tasks					
2.1.1.2.1.1 Prepare for Movement	S		P	S	S
2.1.1.2.1.2 Prepare for Field Operations	S		P	S	S
2.1.1.2.1.3 Data Collection					
2.1.1.2.1.3a Distance	S		P	S	S
2.1.1.2.1.3b Direction	S		P	S	S
2.1.1.2.1.3c Layout Curves	S		P	S	S
2.1.1.2.1.3d Planetabling	S		P	S	S
2.1.1.2.1.4 Process Field Data					S
2.1.1.2.1.4a Topo	S		P	S	S
2.1.1.2.1.4b Construction	S		P	S	S
2.1.1.2.2 Power Requirement	S		P	S	S
2.1.2 Data Transfer					
2.1.2.2.1 Record and Transfer (external)	S		P	S	S
2.1.2.2.2 Transfer and Use (internal)	S		P	S	S
2.2 Non-Critical Evaluation Issues & Criteria					
2.2.1 Demonstrate Adequate RAM					
2.2.1.2.1 MTBOMF	S		P	S	S
2.2.1.2.2 Maintenance Ratio	S		P	S	S
2.2.1.2.3 A_o	S		P	S	S
2.2.2 Electronic Compatibility					
2.2.2.2 EMI	S		P	S	S
2.2.3 Technical Documentation					
2.2.3.2.1 Describe Task Requirements	S		P	S	S
2.2.3.2.2 Enable Task Performance	S		P	S	S
2.2.3.2.3 Reading Grade Level	S	P	S	S	S
2.2.4 Training Program					
2.2.4.2 Tasks to Standards			S	P	S
2 2.5 Logistic Support					
2.2.5.2.1 Repair Parts and Warranties	S		S	P	S
2.2.5.2.2 Organization		P	S	S	S
2.2.5.2.3 Responsibilities		P	S	S	S
2.2.5.2.4 Facilities		P	S	S	S
2.2.6 Transport					
2.2.6.2.1 Using Unit Capability	S	P	S	S	S
2.2.6.2.2 Crew Packaging	S	S	P	S	S
2.2.6.2.3 Equipment Protection	S		P	S	S
2.2.6.2.4 Backpacking	S		P	S	S
2.2.7 Safety					
2.2.7.2.1 No Uncontrollable Hazards	S		P	S	S
2.2.7.2.2 IAW MIL-STDS	S		P	S	S

OBJECTIVE/ISSUE/CRITERIA	DATA SOURCE				
	CT	STUDY	GT	OT	TT
2.2.8 Human Factors Engineering					
2.2.8.2.1 AR Requirements			S	S	P
2.2.8.2.2 Cold Weather Clothing			S	P	S

KEY:

CT = Contractor Test/Data

GT = Government Test/Market Investigation*

OT = Operations Test

TT = Technical Test

P = Primary Source

S = Secondary Source

NOTE: * Includes all government testing/Market Investigation prior to Milestone I.

SECTION IV

4.0 Evaluation Methodology:

4.1 Analytical Techniques: The AISI candidate(s) will be objectively and subjectively evaluated. The evaluation will be based on the performance characteristics of the AISI as specified in the criteria as well as a subjective and objective comparison with other systems which perform the same or similar functions. Data gathered in all testing (contractor, government, foreign government) will be analyzed and, when appropriate, combined to improve the statistical sample size and confidence. All information gathered, including literature search, contractor test, government test, and desk-top analysis, will be evaluated from an operational point of view. Professional and military judgement will be exercised where required to maintain the thrust of the evaluation, i.e., how well does the AISI work in an Army unit, operated and maintained by soldiers, and relying on the Army logistic support system.

4.1.1 Adequacy of Testing and Validity of Test Results: The independent evaluator will examine the quality and suitability of all available data before using it in the IER to ensure it is relative and properly addresses the issues. The evaluator will make reasonable efforts to obtain and review test planning documents, as appropriate, to enhance the validity of the test effort. Direct observation of testing is required. The evaluator will comment on test observations as well as assess the credibility of test report findings based on those observations.

4.1.2 Effects of Testing Limitations: The evaluator will assess the effects test limitations have on the evaluation, particularly in the areas of performance, RAM, training, and logistic supportability. Also, physical characteristics as they affect transportability will be assessed. These effects and the degree of degradation they have on the evaluation will be reported in the IER.

4.1.3 Analysis of Issues:

4.1.3.1 The performance of AISI candidate(s) will be compared to criteria, stated in this IEP, to determine if all issues have been answered or addressed. Additionally, if practical, the AISI candidate(s) performance will be compared to existing systems which perform the same or similar functions as stated in paragraph 4.1.

a. These comparisons will be analyzed to determine the degree to which the criteria were or were not met, or the degree to which the various AISI candidate(s) capabilities exceed or are less than the current systems.

b. The analysis will address the impact that shortcomings have on the AISI in terms of manpower support resources, operational procedures and mission accomplishment.

c. A conclusion will be made for each issue, based on the analysis, as well as an assessment of the operational impact of the findings.

4.1.3.2 GT and the Market Investigation are to provide most of the information to be used in the evaluation. The Market Investigation projected is expected to provide technical and engineering design data, and assess the performance when measured against appropriate MIL-STDs. GT is expected to provide an assessment of the military utility of the AISI as it is employed by soldiers in a field environment.

4.1.4 Conclusion: In addition to conclusions associated with each issue, the independent evaluator will make conclusions on the adequacy of testing, further testing, and further development efforts.

4.1.5 <u>Operational Effectiveness/Military Utility</u>: A statement of each AISI candidate's ability to perform its mission, highlighting advantages and disadvantages, will be included in the IER. The final statement will --

a. Indicate the candidate's ability to perform its mission.

b. Assess the ability of soldiers to use the system.

c. Include any special logistic considerations.

d. State the overall utility of the candidate to the Army.

4.2 <u>Test Concepts</u>:

4.2.1 <u>User/Operational Test</u>: U/OT will be used to evaluate the ability of the using soldier to effectively employ the AISI. Specifically, U/OT will address such issues as mission performance, RAM, personnel selection, training, organization, doctrine, logistics, human factors and safety. U/OT will provide data on the operational performance of the AISI under simulated tactical situations.

4.2.2 <u>Technical Test</u>: TT will be used to evaluate technical performance, human engineering characteristics, climatic and safety requirements in support of this operational evaluation.

4.2.3 <u>Force Development Testing and Experimentation (FDTE)</u>: None planned.

4.2.4 <u>Contractor Test</u>: Prototype and production testing will be conducted IAW AR 702-9, Production Testing of Army Materiel. Relevant data bearing on an issue will be utilized in evaluating the AISI as appropriate.

4.3 <u>Nontest Concept</u>:

4.3.1 <u>Wargames/Simulations</u>: None planned.

4.3.2 <u>Pertinent Studies</u>: The cost and operational effectiveness and analysis (COEA) will be used as a data source for evaluation of criteria having an interface with data in this evaluation. Applicable studies will be conducted by the Belvoir Research and Development and Engineering Center and will be used for full or partial evaluation of specified issues as identified in the dendritic data source matrix at Section III and for other problem areas as may be identified in testing.

4.3.3 Personnel Documents: The system's IQQPRI and PQQPRI, integrated coordinated test plan, TOE's, logistic support analysis documents, AR 611-201, and the system's software and training documentation will be used for evaluating criteria for issues that have a personnel interface.

4.3.4 Other: None.

APPENDIX A

MAJOR MILESTONES

Automatic Integrated Survey Instrument (AISI)

Milestone	Responsibility	Date
ROC	USAES	1978
O&O Plan (approved)	USAES	1QFY87
IEP Approval	USAES	4QFY87
Acquisition Strategy	BRDEC	4QFY87
Market Investigation/ User Demonstration	BRDEC	4QFY87
Milestone I/III IPR	BRDEC	2QFY88
PAT&E	TROSCOM	4QFY89
FUE	TROSCOM	2QFY90
FOT&E	TRADOC	3QFY90

APPENDIX B

POINTS OF CONTACT

Automatic Integrated Survey Instrument (AISI)

Agency	Office	POC	Telephone
BRDEC (Mat Dev)	STRBE-JCT	Mr. Mark Thomas	AV 354-6784
USAES (Cbt Dev)	ATZA-CDM	Mr. Harold Hester	AV 354-4505
TECOM (DIE)	AMSTE-EV-S	Mr. Joe Andrese	AV 298-5221
USAES (OIE)	ATZA-CDT	Mr. Ralph Redmond	AV 354-3346
BRDEC	STRBE-TIC	Mr. Frank McLaughlin	AV 354-4272
DMS	GSS	Mr. Thomas Besch	AV 354-1087
Toole Army Depot	SDSTE-FM-I	Mr. Clayd O. George	AV 790-2964

APPENDIX C

OPERATIONAL MODE SUMMARY/MISSION PROFILE

Automatic Integrated Survey Instrument (AISI)

THREAT	WEAPONS POSING THREAT TO SYSTEM		
	DIVISION	CORPS	THEATER ARMY
Small Arms	X	X	X
Artillery	X	X	
Missile	X	X	X
Tactical		X	X
Guerrilla/Unconventional Warfare	X	X	X

MISSION: To provide horizontal coordinates, elevations, azimuths, and hard copy output using field survey methods at the accuracy required for accomplishing the theater geodetic, topographic, construction, and artillery and missile fire missions. Basically, the topographic surveyor in wartime furnishes the field artillery weapons positioning and azimuth control on a continuing basis 12 hours each day, 7 days a week. Peacetime normally is solidifying and densifying control on an as needed basis 10-hour days and 5-day weeks. Construction surveyors in wartime run route reconnaissance, survey in bridges, roads, airfields, culvert, etc., 12-hour days, 7-day weeks. Peacetime, the only difference is the week is shortened to 10-hour days and 5-day weeks.

WEATHER EXTREMES: Climatic design types: hot, basic, and cold as defined by AR 70-38, Table 2-1 and MIL-STD 210B.

<u>Percent Wartime and Peacetime Operational Times</u>:

	# WARTIME	# PEACETIME
HOT	40	5
BASIC	50	90
COLD	10	5

TASKS: To provide survey information and hard copy output as required by the supported unit.

MOVEMENT PROFILE: The AISI will have the same transportability characteristics as present transportable (mobile) survey instruments. Field parties normally travel in 5/4 ton CUCV vehicles, survey company personnel move in 1/4 ton trucks, 5 ton cargo trucks, and the Topographic Support System's (TSS) 5 ton tractor survey section.

<u>Normal Transportation Profile for Topo/Construction Survey Parties</u>:

Cross Country	60%
Highway	20%
Off Road (secondary)	20%

Basis of time estimates is one three man crew determining position azimuth and elevation in a three station traverse with a known starting point. A typical daily wartime/peacetime mission total can not be provided (other than that stated below under Operation Summary) as many factors such as weather, terrain, density of control, requirements, etc., enter into the total amount of work which can be completed by a typical survey crew in a typical day. (See mission for total times expended.)

TASK*	Conventional Topo	Conventional Const	AISI

*There is no differentiation of tasks between wartime and peacetime. All tasks are performed as noted.

1. Preparation for movement	15 min	15 min	15 min
2. Preparation for field operations (set-up)			
a. Distance Measurement	5 min	5 min	5 min
b. Direction Measurement (horiz & vert)	8 min	8 min	8 min

		Conventional		
	TASK*	Topo	Const	AISI
3.	Conduct data collection			
	a. Distances	5 min	3 min	2 min
	b. Directions (horiz & vert)	12 min	6 min	10 min (Topo) 5 min (Const)
	c. Layout Curves (per point)	N/A	3 min	1 min
	d. Planetabling (per point)	3 min	3 min	1 min
4.	Process field data	2-3 hrs	2-3 hrs	3-5 min**
5.	Operator/Organizational Servicing	15-30 min	15-30 min	15-30 min

**Dependent upon amount of stations in traverse scheme.

OPERATING SUMMARY:

Basis of time estimate is one three-man crew determining position azimuth and elevation in a three-station traverse with a known starting point.

	Conventional (topo/const)	AISI
Acquiring survey info	40%	15%
Not acquiring survey info	60%	85%
Total time at station	259 min	77 min

APPENDIX D

FAILURE DEFINITION/SCORING CRITERIA (FD/SC)

Automatic Integrated Survey Instrument (AISI)

TO BE PUBLISHED

APPENDIX E

COORDINATION

Automatic Integrated Survey Instrument (AISI)

Independent Evaluation Plan (IEP)

1. The draft IEP for the AISI was coordinated during the period Jul-Aug 87. Comments were received and accommodated as noted in the following paragraph.

2. Comment Matrix:

Source	Received	Accepted	Accepted In Part	Not Accepted	Remarks
USATRADOC					
ATOS	0				#1
ATCD-T	0				#3
ATTG-Y	0				#1
ATEN-S	0				#3
ATDO-C	0				#1
ATCD-I	0				#3
USACAC	7	7			#2
USALOGC	0				#3
USASSC-NCR	0				#1
USAOTEA	5	3		2	#4
USA Safety Center	0				#3
USATCATA	1	1			#2
USABRDEC	1	1			#2
USALEA	0				#1
USATECOM	0				#3
USAMSAA	12	9		3	#4
USATSC	0				#1
USAAHS	0				#1
USAHEL	0				#3
USAES (ATZA-DTD)	0				#3
USAARENBD	1			1	#2

REMARKS:

#1 Concur as Written
#2 Concur with Comments
#3 No Response Provided
#4 Nonconcur/Concurrence Withheld

3. Two agencies nonconcurred or withheld concurrence during the staffing of this IEP. Responses to their nonconcurrences are as follows:

USAOTEA: This agency withheld concurrence pending development of the RAM criteria values and the associated rationale.

Response: RAM criteria values are not developed as part of the IEP but are extracted from requirements documents. A RAM issue is identified in the IEP but the actual values are TBD. Since these values are developed, staffed, and approved in a śeperate document, the IEP is forwarded for approval now and the RAM values will be added when they are approved.

USAAMSAA: This agency nonconcurred because the IEP did not discuss survivability/vulnerability of the AISI.

Response: At present the AISI requirements documents do not identify survivability/vulnerability parameters for this system. The acquisition strategy for AISI is for a NDI approach. As such survivability/vulnerability requirement will probably be minimal. However, if such requirements are identified in the future, the AISI IEP will be updated accordingly.

4. The following are comments that were accepted in part or were not accepted for inclusion in the IEP.

USAARENBD:

Comment #1, p 2-5: Issue 2.2.4 (Training) should be designated as a critical issue.

Reason not accepted: The user has not identified training as a critical issue for AISI. Although training is essential to operation of AISI, the tasks should be very similar to those already taught military operators projected to employ the AISI.

USAMSAA:

Comment #6, p 2-9: Add "and NBC clothing" after "cold weather clothing."

Reason not accepted: The AISI O&O Plan does not specify a requirement to operate the AISI in an NBC environment. If this becomes a requirement in the future, the IEP will be changed to reflect the NBC clothing requirement.

Comment #10: The document fails to identify the extent to which the AISI will survive in a hostile environment (Survivability/Vulnerability). As a minimum, the effects of electromagnetic radiation (EMR) and electromagnetic pulse (EMP) on the AISI as well as the effects of Nuclear, Biological, and Chemical (NBC) contamination and decontamination should be assessed. In addition, the operability of the AISI by a user in full MOPP gear should be considered as a Human Factors Engineering (HFE) issue. Due to the fact that the AISI will be extensively used in wartime (12 hours a day/7 days a week) the vulnerability of the digital theodolite, microprocessor, data recorder, etc., should be validated.

Reason not accepted: At present, the AISI O&O Plan does not specify a survivability/vulnerability requirement. If EMR, EMP, NBC contamination/decontamination survivability are identified as requirements in the future, the AISI IEP will be updated accordingly.

Comment #12: All the operational issues for the AISI are stated as "yes/no" issues. While this may be technically acceptable, reference 6c advocates, at least for AMSAA, trying to avoid critical issues which can be answered with "yes or no." Rarely are there situations which involve simplistic pass or fail criteria, therefore, the yes or no criteria do not define how well a system truly meets the Army's needs. Instead, the issues should be rephrased to address the various levels.

Reason not accepted: AISI issues and criteria are currently written in accordance with guidance from the approving authority, USACAC, TIED. It is agreed that the evaluation is much more than a yes or no answer, however, answers are provided in the evaluation report not the plan. Scope paragraphs include requirements for the tester to report actual performance data not just a pass/fail answer.

USAOTEA

Comment #3, p 2-2, para 2.1.1.3: Indicate what the individual task times will equate to in terms of total times for typical topographic and construction survey tasks.

Reason not accepted: Total times to complete survey tasks are highly dependent on terrain and environmental factors. Given the variables, it is felt the most cost effective comparison is a comparison of individual tasks tempered by military judgement.

Comment #5, p 4-1, para 4.0: This section does not adequately address the evaluation methodology or analytical techniques to be used. The evaluator must specify, in detail, i.e., on an issue-by-issue basis, how each of the issues and associated criteria will be evaluated and the specific analytical techniques to be utilized.

Reason not accepted: As currently written, this section complies with guidance from the approving authority, USACAC, TIED.

APPENDIX F

REFERENCES

Automatic Integrated Survey Instrument (AISI)

Independent Evaluation Plan (IEP)

1. AR 70-1, System Acquisition Policy and Procedures, 12 Nov 86.

2. AR 70-10, Research, Development, and Acquisition: Test and Evaluation (Final Draft), 11 Aug 86.

3. AR 71-3, User Testing, 21 Jan 86.

4. AR 350-35, New Equipment Training and Introduction.

5. AR 702-3, Revised AR 702-3, Army Material Reliability, Availability, and Maintainability (RAM), with LOGC Ltr, dtd, 5 May 87.

6. DA Pam 71-3, Operational Testing and Evalaution Methodology and Procedures Guide, 15 Oct 79.

7. TRADOC Reg 71-9, User Test and Evaluation, 25 Jan 82 w/ch 2.

8. TRADOC Pam 71-13, Independent Evaluation Methodology and Procedures, 9 Sep 83.

9. TRADOC Pam 71-15, User Testing.

10. TRADOC/DARCOM Pam 70-2, 26 Mar 87.

11. Required Operational Capability (ROC) for an Army Topographic Support System (TSS), TRADOC ACN 20393, 20 Jan 76, U.S. Army Engineer School, ATZA-CDM, Fort Belvoir, VA 22060.

12. Operational and Organizational Plan for the Automatic Integrated Survey Instrument (AISI), TRADOC ACN 073751, 15 Oct 86, U.S. Army Engineer School, ATZA-CDM, Fort Belvoir, VA 22060.

APPENDIX G

STAFFING AND DISTRIBUTION

Automated Integrated Survey Instrument (AISI)

Independent Evaluation Plan (IEP)

Agency	Draft	Apvd
COMMANDER USACAC & FORT LEAVENWORTH ATTN: ATZL-TIE FORT LEAVENWORTH, KS 66027-5130	C	I
COMMANDER USALOGC ATTN: ATCL-M FORT LEE, VA 23801-6000	C	I
COMMANDER USASSC-NCR ATTN: ATNC-NMM 200 STOVALL STREET ALEXANDRIA, VA 22332-0400	C	I
COMMANDER OTEA ATTN: CSTE-ZX 5600 COLUMBIA PIKE FALLS CHURCH, VA 22041-5115	C	I
COMMANDER USA TRADOC	C	I
ATTN: ATCD-T (5212)	C	I
ATTG-Y (5313)	C	I
ATEN-S (5431)	C	I
ATDO-C	C	I
ATCD-I FORT MONROE, VA 23651	C	I
DIRECTOR USA SAFETY CENTER ATTN: SYS MGR FORT RUCKER, AL 36362-5363	C	I

C = Provided for Comments/Concurrence
I = Provided for Information

Agency	Draft	Apvd
COMMANDER USATCATA ATTN: ATCI-MA FORT HOOD, TX 76544-5065	C	I
COMMANDER BRDEC ATTN: STRBE-JCT FORT BELVOIR, VA 22060	C	I
COMMANDER USALEA ATTN: DALO-LEI NEW CUMBERLAND ARMY DEPOT NEW CUMBERLAND, PA 17070-5007	C	I
COMMANDER USATECOM ATTN: AMSTE-TO ABERDEEN PROVING GROUND, MD 21005-5071	C	I
DIRECTOR USAMSAA ATTN: AMSY-CR, AMSY-D ABERDEEN PROVING GROUND, MD 21005-5071	C	I
COMMANDER USATSC ATTN: ATIC-DS FORT EUSTIS, VA 23604	C	I
PRESIDENT USAARENBD ATTN: ATZK-AE-EN FORT KNOX, KY 40121-5470	C	I
COMMANDANT AHS, USA FORT SAM HOUSTON, TX 78232	C	I
DIRECTOR USAHEL ATTN: AMXHE-AM ABERDEEN PROVING GROUND, MD 21005-5055	C	I
COMMANDANT USAES ATTN: ATZA-DTD FORT BELVOIR, VA 22060	C	I

FGCC

Test and Evaluation of Total Station Instruments

FGCC Report: FGCC-IS-87-1

Stephen R. DeLoach

January 1987

US Army Corps of Engineers

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Test and Evaluation of Total Station Instruments

FGCC Report: FGCC-IS-87-1

Stephen R. DeLoach
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Rockville, Maryland

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Rockville, Maryland 20852

January 1987

CONTENTS

TABLES

Mention of a commercial company or product does not constitute an endorsement by the Federal Geodetic Control Committee. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

TEST AND EVALUATION OF TOTAL STATION INSTRUMENTS

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ABSTRACT. Total station instruments, which combine an electronic distance measuring instrument and a theodolite, have been widely accepted by the surveying community to perform geodetic surveys as well as other types of measurements. In response to this new technology, the Federal Geodetic Control Committee (FGCC) tested the following total station instruments: Geodimeter 142, Kern E2, Lietz SET 3, Nikon DTM-1, Topcon ET-1, and Wild T2000. The objective was to determine the relationship between the capabilities of the new instruments and the specifications for geodetic surveys as given in the FGCC publication Standards and Specifications for Geodetic Control Networks. Field observations were made using each instrument between November 1985 and July 1986. A thorough evaluation of these data indicates that these instruments are fully capable of performing geodetic quality horizontal surveys when proper procedures are followed. Establishing geodetic quality elevations was less successful; however, it may be possible to develop new techniques to take advantage of this potential.

INTRODUCTION

Recent advances in technology have created many new tools for the surveyor. One of these, the total station, has been widely accepted by the surveying community to perform various types of measurements including geodetic surveys.

Essentially, a total station is a combination of two instruments: an electronic distance measuring instrument (EDMI) and a theodolite. This arrangement creates a convenient field unit with actual operational characteristics similar to the older style instruments. Major changes warranting attention are the increased capabilities built into the new units as a result of advances in electronic technology.

In response to this emerging technology the FGCC began testing various total station instruments. The objective was to determine the relationship between the capabilities of the new instruments and the specifications for geodetic surveys as given in the FGCC publication Standards and Specifications for Geodetic Control Networks (1984). This report describes instrument testing and subsequent data analysis.

The published specifications are divided into the following sections: Network Geometry, Instrumentation, Calibration Procedures, Field Procedures, and Office Procedures. Covered under these categories are triangulation, traversing, and geodetic leveling. This evaluation deals only with those items that are dependent on an instrument's capabilities. For example, astronomic azimuth spacing, which is not dependent on a particular instrument, was not considered. Six instruments were tested:

Geodimeter	142
Kern	E2/DM503
Lietz	SET 3
Nikon	DTM-1
Topcon	ET-1
Wild	T2000/DI5

DESCRIPTION OF TEST

Equipment tests were conducted by the Instrument and Equipment Section of the National Geodetic Survey (NGS) at its facility in Corbin, Virginia. Testing, which consisted of the phases discussed below, took place between November 1985 and July 1986. The actual sequence of tests was dictated by weather and available personnel.

Instrument Familiarization

The primary person performing these tests and the principal instrument operator spent one day becoming familiar with the functions and characteristics of a given instrument. Because various functions differed from instrument to instrument, this initial procedure determined the modifications required in data collection to accommodate a particular instrument.

Sensitivity Tests

Prior to performing the field measurements each instrument was bench tested to check for level vial sensitivity, horizontal and vertical collimation error, cross hair linearity, and automatic compensator sensitivity. The purpose of these tests was to verify that the instrument was operating to the manufacturer's specifications. These tests were used as prequalifiers prior to actual field testing. Therefore, the results are not published. An instrument was field tested only after the sensitivity testing showed it performed to acceptable standards.

These tests proved valuable to the overall project because several instruments were returned to the manufacturers for adjustments prior to field testing.

Automatic Compensator Sensitivity

This test was performed to check the function of the instrument's automatic compensator. It was performed on a test instrument, called a Level Trier, developed by NGS personnel at Corbin.

The Level Trier consists of a platform mounted on a beam hinged at one end and supported by a very finely threaded screw at the other end. The screw has a dial attached to it which is graduated such that one division of the dial, from the fixed index, tilts the platform 1" (arc second). Thus, the platform may be tilted through an arc of several minutes very accurately and the vertical angle correction of the instrument may be conveniently checked.

The test is performed by setting the Level Trier dial to zero and carefully leveling the instrument on the platform. The telescope is aligned with the beam and the vertical angle set to 90°. Then the Level Trier is tilted 10" by turning the dial and the vertical angle is recorded. This is repeated until the instrument has been tilted 1' (arc minute). Then the vertical angle is changed 10° and the instrument is tilted through one more minute of arc in 10" increments. Now the Level Trier is reset, the angle is changed 10°, and the sequence is repeated. The observed change in the vertical angle should correspond to the amount of tilt set into the Level Trier. The range of vertical angles checked was limited from 45° above the horizon to 45° below the horizon, this being considered the most commonly used range.

Determination of Sensitivity and Level Vial Value

The purpose of this test was to determine the sensitivity and value in arc seconds of the level vial on each of the instruments. The level tube used in surveying instruments is a glass vial with the inside ground barrel-shaped, so that a longitudinal line on its inner surface is the arc of a circle. The tube is nearly filled with a 50-50 mixture of sulfuric ether and alcohol. The remaining space is occupied by a bubble of air that takes up a location at the high point in the tube. The tube is usually graduated in both directions from the middle; thus, by observation of the ends of the bubble it may be centered, or its center brought to the midpoint of the tube.

A longitudinal line intersecting the curved inside surface of the bubble at its upper midpoint is called the "axis of the level tube." When the bubble is centered, the axis of the level tube is horizontal.

If the radius of the circle to which the inner chamber of the level tube is ground is large, a small vertical movement at one end of the tube will cause a large displacement of the bubble; if the radius is small, the displacement will be small. Thus the radius of the tube is a measure of its sensitivity. The sensitivity is generally expressed in the number of seconds of arc of the central angle, for one division marked on the tube. For most instruments the length of a division is 2 mm. The sensitivity expressed in seconds of arc is not a definite measure unless the spacing of graduations is known.

This test was also performed on the Level Trier. Basically, the level bubble was moved through the range of its scale, and readings were taken simultaneously on the bubble and Level Trier micrometer. The amount which each end of the bubble moves for each new setting of the micrometer is computed, "difference, left and right." To detect irregularities in the level vial, values were computed by dividing the interval between successive micrometer readings by the number of divisions the bubble moves between observations. The level value for each set of observations was derived by summing successively computed values and dividing by the number of computed values. The final value was determined by summing the level values from each set of observations and dividing by the number of sets.

Horizontal and Vertical Collimation Check

Each instrument was tested for horizontal and vertical collimation errors. The instrument was adjusted so that there was no parallax in the telescope for the individual observer performing the test. After careful leveling a pointing was made in the direct position at the infinity target in a visual collimator. The instrument was reversed and pointed at the same target. Both horizontal angles were recorded. This procedure was repeated six times. The sum of the mean direct and reverse pointing should equal 360° 00' 00". If the collimation was greater than 10", appropriate adjustments to the cross hairs were made.

To check for vertical collimation, the instrument was again carefully leveled and pointed at the infinity target in a visual collimator. The appropriate calculations were performed and any required adjustments made to ensure a minimum collimation error.

Cross hair Linearity

This test was done to ascertain that the vertical and horizontal parts of the cross hair were truly vertical and horizontal, respectively. This check was performed by simply pointing the vertical cross hair at a well-defined point and observing that point while the telescope was moved vertically through the field of view. The same was done with the horizontal cross hair. Any observed deviation was corrected by cross hair adjustment.

EDMI Calibration

The electronic distance measuring instrument (EDMI) test was performed on the Corbin Calibration Base line in accordance with NOAA Technical Memorandum NOS NGS-10, "Use of calibration base lines" (1980). The collected data were reduced and a least squares adjustment performed. This adjustment yielded the following information:

1. Combined atmospheric and instrument scale error.
2. Combined reflector and EDMI constant.
3. Variance of unit weight, based on the instrument manufacturer's stated accuracy.
4. Standard error of scale error determination.
5. Standard error of EDMI and reflector constant.

Appendix A contains published values for the Corbin Calibration Base Line.

Calibration Base Line Procedures

Each station in the base line has a permanent instrument stand. Prior to occupying each station the top of the stand was collimated over the mark using a Wild Model NL optical plummet.

Observations were taken to a target-reflector combination, mounted on a 15 cm offset bar. A complete set of observations consisted of 10 readings to the +15 and -15 cm positions and 20 readings to the 0 position.

Air temperatures were measured at both ends of the line being observed. The measuring devices were digital aspirated thermistors having an accuracy of ±0.1°C. The temperatures were measured at the beginning and end of each bar position. The sensor probe was elevated at least 3 m above the ground and was kept in the shade. The thermistors were periodically checked with thermometers calibrated by the National Bureau of Standards in Gaithersburg, Maryland. Along with temperature, barometric pressure and water vapor content of the atmosphere were measured before and after each bar position at each end of the line. Barometric pressure was measured with Wallace and Tiernan barometers having an accuracy of ±0.5 mm of mercury. The barometers were periodically checked with a laboratory mercury column. Atmospheric water vapor content was measured with a Bendix aspirated psycrometer.

All data from the calibration base line were recorded on a Radio Shack Model 100 portable computer. Appendix B lists a sample output of the data collector.

Total Function Test

This test was performed by occupying four points on the Corbin test quad. Each station has a 1.3 m stand firmly anchored in the ground and topped by a specially fabricated adjustable tribrach. Before occupying each station, the adjustable tribrach was collimated using a Wild NL optical plummet. A special attachment was fabricated to measure the height above the mark of each tribrach to +0.1 mm. This height was also measured each time the station was occupied. Next, a Wild GDF6 type tribrach was fastened to the adjustable tribrach on the stand and carefully leveled with a specially adapted, and calibrated, level vial.

The targets used were designed with a retro-reflector at the center of a metal plate, which had one vertical and one horizontal stripe to permit sighting the center of the reflector. Two more horizontal stripes were placed above and below the reflector at distances corresponding to the offset between the optical axis and EDMI axis of each instrument that was not made coaxial. White stripes on a black background were chosen for maximum contrast and ease of pointing.

Each station of the quad was occupied with each instrument three times, each time with a different observer. Each observer measured horizontal directions using 16 plate positions (either electronic or mechanical) with direct and reverse pointings. Sixteen sets of zenith distances, or vertical angles, were observed in circle left and circle right. Slope distances were also measured 16 times. The difference of elevation, or delta h function, was also observed and recorded. Temperature, barometric pressure, and water vapor content were measured for each set of observations. The instrument was always shaded by an umbrella.

Data Collection and Processing Systems

Owing to the amount of data accumulated in testing the total station instruments, the observing, recording, checking, and reduction of the measurements were a lengthy process. To reduce the time involved, a data collection and processing system was developed.

The system hardware consists of a Radio Shack Model 100 portable computer, a portable 3-1/2 inch floppy disc drive, and printer. Software for both recording measurements and processing data was developed and written on the Model 100 by Mr. Orland Murray of the NGS Instrument and Equipment Section.

The Model 100 and data recorder program functioned as an electronic field book for all observations on the test quad. All instrument information (manufacturer, type, serial number, etc.), standpoint and forepoint information (name, height of tripod, height of instrument, etc.), and observed measurements were entered into the computer.

The program provides thorough error checking at the point of entry of the data to avoid blunders and minimize later editing. All entries are prompted for and easily corrected if miskeyed. As observations proceed, information such as horizontal and vertical collimation are displayed to allow the user to monitor the data and detect any discrepancies in the observations. The program also provides ample opportunity for entering comments during observations.

Data sets are organized by unique file name and consist of 16 direct and reverse positions. At each position horizontal directions, zenith distances, EDMI slope distances, and differences of elevation are recorded. Only direct EDMI distance measurements are entered in cases where reverse measurements were not possible due to instrument configuration. Each file also contains information about the instrument, standpoint, forepoints observed, and any other information pertinent to that set of observations.

Each of the data reduction programs performs the following:

1. Reads the respective data from the observation files produced by the data collection program.

2. Reduces data according to standard NGS procedures (means direct and reverse, computes corrected slope distances, etc.)

3. Prints a hard-copy field book of all the raw data and reductions.

4. Computes and prints either an abstract or summary of reduced data, which includes a mean and standard deviation of a single observation, except for differences of elevations shown on page 43.

Appendix B contains examples of the computer printouts.

No manipulation of the data is performed other than standard NGS reductions for field observations. The means and standard deviations are not held to any tolerances or rejection limits. Data were edited to eliminate obvious errors. These show up readily on the abstracts or summaries. After completing more than 15,000 independent observations as part of the total station testing, less than 1 percent of the data had to be rejected due to equipment failures or blunders.

The Model 100 system was also used for recording the base line observations. The software developed functions similar to the quad software by utilizing input error checking and feedback to the user during observations. Data sets are organized by unique file name and consist of instrument description, reflector description, from and to base points, meteorological data observations, distance measurements, instrument horizontal distance, base horizontal distance, and difference between instrument and base distances.

Each file constitutes one complete set of EDMI distance measurements over a given segment of the base line. After all observations are entered, the program applies all corrections, reduces corrected slope distance to horizontal distance, and computes the difference between the instrument's horizontal distance and the known base horizontal distance. Finally, files are saved to each of two floppy discs. With the exception of later printing a hard copy of the files, no further processing of observation data is needed.

The primary output of each file is the difference between EDMI length and base length. These values are used in the least squares adjustment program that determines the scale correction, constant correction, variance of unit weight, and standard errors of both scale and constant corrections for the respective EDMI.

DATA ANALYSIS

Data analysis was performed to determine the relationship between the capabilities of each instrument and the specifications for geodetic surveys as given by the FGCC (1984). Table 1 lists the specifications considered.

The following sources of information were used to determine which order and class requirements a particular instrument could satisfy:

1. Manufacturer's specifications.
2. Field books generated by the data processing systems.

When field books were used, the data under a particular category were summarized and the statistical properties of the mean value, standard deviation, and sometimes the standard deviation of the mean were computed. As an example, a total of eight horizontal angles were measured by three observers. Each observer measured each angle with 16 positions, direct and reverse. The standard deviation of the mean was then computed from this total set containing 384 observations (8×3×16).

The following definitions were used for the statistics:

The sample mean is

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \qquad (1)$$

The standard deviation of a single observation is

$$\sigma_X = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (X_i - \bar{X})^2} \qquad (2)$$

and the standard deviation of the mean,

$$\sigma_{\bar{X}} = \frac{\sigma_X}{\sqrt{n}} \qquad (3)$$

where X_i is the ith observation and n is the number of observations.

Table 1.--Federal Geodetic Control Committee specifications for geodetic control surveys

		Order/Class				
		I	II/I	II/II	III/I	III/II
1. Network geometry						
Station spacing	T	15	10	5	0.5	0.5
not less than (km)	L	10	4	2	0.5	0.5
2. Instrumentation						
Theodolite, least	T	0.2"	0.2"	1.0"	1.0"	1.0"
count	L	0.2"	1.0"	1.0"	1.0"	1.0"
3. Field procedures						
3a. Directions						
Number of positions	T	16	16	12	4	2
	L	16	12	8	4	2
Standard deviation						
of mean not to	T	0.4"	0.5"	0.8"	1.2"	2.0"
exceed	L	0.4"	0.5"	0.8"	1.2"	2.0"
Rejection limit	T	4"	4"	5"	5"	5"
from mean	L	4"	5"	5"	5"	5"
3b. Reciprocal vertical angles						
No. of independent	T	3	3	2	2	2
observations D/R	L	3	3	2	2	2
Maximum spread	T	10"	10"	10"	10"	20"
	L	10"	10"	10"	10"	20"
3c. Infrared distances						
Minimum number of	T	-	10	10	10	10
readings	L	10	10	10	10	10
Maximum difference						
from mean of	T	-	5	5	10	10
observations (mm)	L	10	10	10	-	-
4. Office procedures						
Triangle closure						
average not to	T	1.0"	1.2"	2.0"	3.0"	5.0"
exceed						
5. Geodetic leveling						
field procedure		I	I/II	II/I	II/II	III
Maximum loop						
misclosure (mm)		$4\sqrt{k}$	$5\sqrt{k}$	$6\sqrt{k}$	$8\sqrt{k}$	$12\sqrt{k}$
for Corbin quad		2.8	3.5	4.2	5.6	8.5

T = triangulation; L = traverse

The means and standard deviations of all data sets were orginally computed with no rejection limits. Next, published rejection limits were included and new values computed. Due to the overall quality of the data, the incorporation of rejection limits made no significant difference in the results. The values calculated for each instrument tested are given in tables 3 through 8.

The overall accuracy of each instrument was also evaluated by processing the data with the HAVAGO adjustment program. This program, which is described in NOAA Technical Memorandum NOS NGS 17, "The HAVAGO three-dimensional adjustment program" (1979), runs on the HP1000 computer at NGS headquarters. The program outputs positional errors in three dimensions and residuals from each set of observations on a line's distance, azimuth, and vertical angle.

A comparison was made between each of the total station instruments and the base line values for the Corbin quad. The original network was observed with a Geodimeter 112 EDMI, Wild T-3 theodolite, and a Zeiss NI 002 level. The adjustment was run on the original data set and on each of the total stations by inputting estimated observational errors as specified by the individual manufacturer. To compare each of the instruments all errors were forced into the residuals (v) by holding the elevations fixed and setting the refraction to zero. This caused the residuals of the vertical angles to appear larger than they actually were, but it allowed a direct comparison between each of the instruments. The residuals were then used to compute the root-mean-square (rms) error of the distance, azimuth, and vertical angle of each instrument, where

$$rms = \sqrt{\frac{\sum_{i=1}^{n} v^2}{n}} \qquad (4)$$

RESULTS

Based on the HAVAGO output the horizontal positional errors (accuracies) of all the instruments, including the original base network, were at the 2 mm level. The vertical errors (accuracies) for each of the instruments, except the Lietz, was 1 mm. By running several iterations of the Lietz data set, the refraction values were found to be erratic. Further field testing indicated the instrument had a malfunctioning vertical compensator which was not revealed during the bench test. Due to time constraints it was not possible to make repairs and collect a new data set for evaluation. Therefore, no results on vertical angles or elevations are reported for the Lietz.

Table 2 compares the original network with each of the total stations, as summarized from the HAVAGO adjustment. Included for each instrument are the root-mean-square error and adjusted value of the distance, azimuth, and vertical angle on each leg of the Corbin quad.

These results from the HAVAGO adjustment show the ability of each of the total stations to perform very accurate observations. However, a direct comparison of the results of the field work and the major items in the standards and specifications (table 1) gives a more detailed look at an instrument's ability to perform a first-, second-, or third-order control survey. Tables 3 to 8 show the relationship between the capabilities of each

Table 2.--Corbin quad comparison

Instrument	rms	Quad stations (standpoint to forepoint) 1-2	2-3	3-4	4-1
Original network					
Distance (m)	0.0008	122.837	123.438	127.235	150.001
Azimuth	0.7"	46°16'06.6"	135°32'30.9"	214°12'39.0"	316°16'41.8"
Vertical angle	15.2"	89°33'46.6"	89°30'37.0"	90°25'31.1"	90°23'54.8"
Geodimeter					
Distance (m)	0.0005	122.837	123.438	127.233	150.001
azimuth	1.1"	46°16'03.3"	135°32'32.9"	214°12'52.5"	316°16'44.5"
Vertical angle	7.0"	89°33'31.8"	89°30'56.0"	90°25'41.2"	90°24'00.0"
Kern					
Distance (m)	0.0019	122.838	123.440	127.235	150.003
Azimuth	0.9"	46°16'05.1"	135°32'32.9"	214°12'49.3"	316°16'43.6"
Vertical angle	5.5"	89°33'30.2"	89°30'56.5"	90°25'37.1"	90°23'57.0"
Lietz					
Distance (m)	0.0015	122.838	123.439	127.234	150.002
Azimuth	0.8"	46°16'02.7"	135°32'33.6"	214°12'50.9"	[illegible]
Vertical angle	-	-	-	-	-
Nikon					
Distance (m)	0.0016	122.838	123.439	127.234	150.002
Azimuth	0.7"	46°16'02.4	135°32'33.2"	214°12'52.2"	316°16'43.4"
Vertical angle	8.0"	89°33'34.7"	89°30'51.5"	90°25'42.3"	90°24'02.3"
Topcon					
Distance (m)	0.0017	122.836	123.438	127.234	150.001
Azimuth	0.8"	46°16'07.0"	135°32'32.4"	214°12'48.0"	316°16'43.0"
Vertical angle	7.4"	89°33'30.5"	89°30'52.1"	90°25'37.8"	90°23'58.1"
Wild					
Distance (m)	0.0009	122.838	123.439	127.234	150.002
Azimuth	0.8"	46°16'04.2"	135°32'33.9"	214°12'49.4"	316°16'44.0"
Vertical angle	5.8"	89°33'31.1"	89°30'56.1"	90°25'38.4"	90°23'58.7"

of the total stations and the FGCC standards and specifications (1984). Also given for each instrument are the results of the EDMI calibration and the manufacturer's specifications.

The test results for each of these instruments are listed as follows:

INSTRUMENT	TABLE
Geodimeter	3
Kern	4
Lietz	5
Nikon	6
Topcon	7
Wild	8

The values in each of these tables are those calculated by summarizing all the observations for that particular instrument, in each respective category. The results are also listed under the order and class which would be satisfied according to the FGCC standards and specifications.

Under the category Geodetic Leveling, the loop misclosure was computed by summing the difference of elevation (delta h function) around the quad. In other words, the elevations were determined by trigonometric levels.

It should be noted that these results were obtained by highly skilled technicians adhering to stringent procedures. Similar results may not be obtained under other conditions.

SUMMARY

The intent of this test was to establish the relationship between the capabilities of some of the new total station instruments and the Standards and Specifications for Geodetic Control Networks. To make this comparison each of the instruments was used in a series of observations on a test network previously established at the NGS Corbin facility. The observations from each instrument were then adjusted with the HAVAGO least squares program. The original data set used to establish the network was also adjusted with HAVAGO. A direct comparison was then made between the original network and each of the total stations. This comparison examined the three-dimensional positional errors and the root-mean-square of the adjusted distances, azimuths and vertical angles. The errors showed good correlation between each of the total stations and the original network except in the case of the Lietz instrument. This instrument was found to have a faulty vertical compensator, and the values for the vertical angles and elevations were erratic. Due to various constraints the FGCC did not allow the manufacturer to make the necessary repairs in time for further testing.

The next step in the evaluation was to compute the mean and standard deviations of various observation parameters and to compare them with the published specifications.

In horizontal directions the instruments showed full capability to perform to first- and second-order specifications. The distances were well within first-order standards, but their range limited their use to lower orders. The vertical angles also exceeded first-order standards. Combining the distances and vertical angles (delta h function) to perform trigonometric leveling

yielded results in the second- and third-order geodetic leveling classification. However, the differences of elevation were not consistent at these accuracies, often falling below the FGCC specifications. This inconsistency was probably caused by atmospheric refraction and insufficient field procedures to minimize this error source.

The new technology used in the modern total stations has created a convenient field unit with many capabilities for fast, efficient operation and data transfer. When following proper procedures these instruments show full potential to perform geodetic quality horizontal surveys. Establishing geodetic quality elevations was less successful. It may be possible, however, to develop new techniques to take advantage of this potential.

ACKNOWLEDGMENTS

The testing and evaluation of these new instruments required a tremendous amount of data collection and processing to reduce the final conclusions to a few tables and paragraphs. Without the assistance of many talented people this effort would not have been possible. Therefore, I would like to express my thanks to Messrs. Klaus Drehman, Charles Glover, Orland Murray, Richard Wright and Mrs. Renee Shields of the National Geodetic Survey, and Mrs. Donna Tyson and Mr. Jeffrey Walker of the U.S. Army Engineer Topographic Laboratories.

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Fronczek, C., 1977, rev. 1980: Use of calibration base lines, NOAA Technical Memorandum NOS NGS-10. National Geodetic Information Center, NOAA, Rockville, MD 20852, 38 pp.

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Table 3.[illegible]A Geotronics manufacturer's specifications

Model		Geodimeter 142
Serial number		48076
Configuration		Integral non-coaxial
Telescope		
Magnification		30X
Objective aperture		40 mm
Angulation		
Accuracy:	horizontal	1 "
	vertical	1 "
Least count		1 "
EDMI		
Range:	1 prism	2500 m
	3 prism	3600 m
	6 prism	4500 m
	8 prism	5500 m
Accuracy		± 2 mm + 3 ppm
Resolution		0.1 mm
Wavelength		0.9[illegible]0 nm
Modulation frequency		14985528 Hz

(continued)

Table 3.--Continued

Geodimeter 142 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T			5.5		
	L		5.5			
INSTRUMENTATION						
Theodolite, least	T			1.0"		
count	L		1.0"			
FIELD PROCEDURES						
Directions						
Standard deviation	T			.59		
of mean not to	L			.59		
exceed						
Rejection limit	T	4"				
from mean	L	4"				
Reciprocal Vertical Angles						
Maximum Spread	T	1.8"				
	L	1.8"				
Infrared Distances						
Maximum difference	T	-	* See EDMI Calibration			
from mean of	L	*	sheet following			
observations (mm)						
OFFICE PROCEDURES						
Triangle Closure not to exceed average						4.1
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)		DID NOT MEET THIRD ORDER (11mm)				

T - Triangulation
L - Traverse

(continued)

Table 3.--Concluded

EDMI calibration
Corbin Calibration Base Line

Geodimeter Model 142 Serial No. 48076

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment.......	±2 mm + 3 ppm
Scale correction................................	+3.40 ppm
Constant correction.............................	-0.6 mm
Variance of unit weight.........................	0.04
Standard error of scale correction..............	±0.45 ppm
Standard error of constant correction...........	±0.21 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reductions.

Table 4.--Kern Swiss manufacturer's specifications

Model		E2
Serial number		325882
Configuration		modular
Telescope	DKM2-A	
Magnification		32X
Objective aperture		45 mm
Ambulation		
Accuracy:	horizontal	0.5"
	vertical	0.5"
Least count		1"
EDMI	DM 503	
Range:	1 prism	3000 m
	3 prism	4500 m
	7 prism	5500 m
Accuracy		± 3 mm + 2 ppm
Resolution		1 mm
Wavelength		0.860 nm
Modulation frequency		14985400 Hz

(continued)

Table 4.--Continued

KERN E2 / DM 503 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T			5.5		
	L		5.5			
INSTRUMENTATION						
Theodolite, least count	T			1.0"		
	L		1.0"			
FIELD PROCEDURES						
Directions						
Standard deviation of mean not to exceed	T	0.35"				
	L	0.35"				
Rejection limit from mean	T	4"				
	L	4"				
Reciprocal Vertical Angles						
Maximum spread	T	1.6"				
	L	1.6"				
Infrared Distances						
Maximum difference from mean of observations (mm)	T	-	*See EDMI calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average	T		1.1"			
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)					5.3	

T - Triangulation
L - Traverse

(continued)

Table 4.--Concluded

EDMI calibration
Corbin Calibration Base Line

Kern DM503 Serial No. 325882

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment........	±3 mm + 2 ppm
Scale correction..................................	+3.65 ppm
Constant correction...............................	+0.7 mm
Variance of unit weight...........................	0.24
Standard error of scale correction................	±1.2 ppm
Standard error of constant correction.............	±0.67 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reductions.

Table 5.--Lietz Sokkisha manufacturer's specifications

Model		SET 3
Serial number		77376
Configuration		Coaxial
Telescope		
Magnification		25X
Objective aperture		45 mm
Angulation		
Accuracy:	horizontal	5"
	vertical	5"
Least count		1"
EDMI		
Range:	1 prism	1000 m
	3 prism	1600 m
Accuracy		± 5 mm + 3 ppm
Resolution		1 mm
Wavelength		0.840 nm
Modulation frequency		14985445 Hz

(continued)

Table 5.--Continued
Lietz SET 3 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T				2.1	
	L			2.1		
INSTRUMENTATION						
Theodolite, least count	T			1"		
	L		1"			
FIELD PROCEDURES						
Directions						
Standard deviation of mean not to exceed	T			0.64"		
	L			0.64"		
Rejection limit from mean	T	4"				
	L	4"				
Reciprocal Vertical Angles						
Maximum Spread	T					
	L					
Infrared Distances						
Maximum difference from mean of observations (mm)	T	-	* See EDMI Calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average				1.5"		
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)						

T - Triangulation
L - Traverse

(continued)

Table 5.--Concluded

EDMI calibration
Corbin Calibration Base Line

Lietz Model SET 3 Serial No. 77376

Observations and least squares adjustment performed according to *NOAA Technical Memorandum* NOS NGS-10.

A priori input to least squares adjustment	±5 mm + 3 ppm
Scale correction	+4.3 ppm
Constant correction	+28.5 mm
Variance of unit weight	0.02
Standard error of scale correction	±0.57 ppm
Standard error of constant correction	±0.32 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reduction.

Table 6.--Nikon manufacturer's specifications

Model		DTM-1
Serial number		84011
Configuration		Coaxial
Telescope		
Magnification		30X
Objective aperture		45 mm
Angulation		
Accuracy:	horizontal	2"
	vertical	3"
Least count		1"
EDMI		
Range:	1 prism	1600 m
	3 prism	2300 m
Accuracy		± 5 mm + 5 ppm
Resolution		1 mm
Wavelength		0.820 nm
Modulation frequency		14972947 Hz

(continued)

Table 6.--Continued

NIKON DTM-1 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T				1.8	
	L				1.8	
INSTRUMENTATION						
Theodolite, least	T			1"		
count	L		1"			
FIELD PROCEDURES						
Directions						
Standard deviation	T			0.55"		
of mean not to	L			0.55"		
exceed						
Rejection limit	T	4"				
from mean	L	4"				
Reciprocal Vertical						
Angles	T	1.9"				
Maximum Spread	L	1.9"				
Infrared Distances						
Maximum difference	T	-	* See EDMI Calibration			
from mean of	L	*	sheet following			
observations (mm)						
OFFICE PROCEDURES						
Triangle Closure						
not to exceed				1.3"		
average						
GEODETIC LEVELING		I/II	I/II	II/I	II/II	III
Maximum loop						
misclosure (mm)						7.8

T - Triangulation
L - Traverse

(continued)

Table 6.--Concluded

EDMI calibration
Corbin Calibration Base Line

Nikon Model DTM-1 Serial No. 84011

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment......	±5 mm + 5 ppm
Scale correction...............................	0.00 ppm
Constant correction............................	+63.8 mm
Variance of unit weight........................	0.04
Standard error of scale correction..............	±0.014 ppm
Standard error of constant correction...........	±0.26 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observation reductions.

Table 7.4--Topcon manufacturer's specifications

Model		ET-1
Serial number		F30109
Configuration		Coaxial
Telescope		
Magnification		30X
Objective aperture		40 mm
Angulation		
Accuracy:	horizontal	2"
	vertical	3"
Least count		1"
EDMI		
Range:	1 prism	1400 m
	3 prism	2000 m
	9 prism	2600 m
Accuracy		± 5 mm + 5 ppm
Resolution		1 mm
Wavelength		0.840 nm
Modulation frequency		14985435 Hz

(continued)

Table 7.--Continued

Topcon ET-1 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T				2.5	
	L			2.5		
INSTRUMENTATION						
Theodolite, least count	T			1"		
	L		1"			
FIELD PROCEDURES						
Directions Standard deviation of mean not to exceed	T			0.57"		
	L			0.57"		
Rejection limit from mean	T			5"		
	L		5"			
Reciprocal Vertical Angles						
Maximum spread	T	1.6"				
	L	1.6"				
Infrared Distances Maximum difference from mean of observations (mm)	T	-	* See EDMI Calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average	T			1.5"		
	L			1.5"		
GEODETIC LEVELING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)						7.1

T - Triangulation
L - Traverse

(continued)

Table 7.--Concluded

EDMI calibration
Corbin Calibration Base Line

Topcon ET-1 Serial No. F30109

Observations and least squares adjustment performed according to *NOAA Technical Memorandum* NOS NGS-10.

A priori input to least squares adjustment........	±5 mm + 5 ppm
Scale correction..................................	-0.90 ppm
Constant correction...............................	+0.2 mm
Variance of unit weight...........................	0.02 (unitless)
Standard error of scale correction................	±0.58 ppm
Standard error of constant correction.............	±0.30 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observations reductions.

Table 8.--Wild Heerbrugg manufacturer's specifications

Model			T2000
Serial number			308310
Configuration			Modular
Telescope	T2		
Magnification			32X
Objective aperture			42 mm
Angulation			
Accuracy:	horizontal		0.5"
	vertical		0.5"
Least count			0.1"
EDMI	DI5		
Range:	1 prism		2500 m
	3 prism		3500 m
	7 prism		4500 m
	11 prism		5000 m
Accuracy			± 3 mm + 2 ppm
Resolution			1 mm
Wavelength			0.845 nm
Modulation frequency			4870255 Hz

(continued)

Table 8.--Continued

WILD T2000/DI5 test results

		ORDER/CLASS				
		I	II/I	II/II	III/I	III/II
NETWORK GEOMETRY						
Station Spacing	T			7.0		
	L		7.0			
INSTRUMENTATION						
Theodolite, least count	T	0.1"				
	L	0.1"				
FIELD PROCEDURES						
Directions						
Standard deviation of mean not to exceed	T	0.33"				
	L	0.33"				
Rejection limit from mean	T	4"				
	L	4"				
Reciprocal Vertical Angles						
Maximum spread	T	1.8"				
	L	1.8"				
Infrared Distances						
Maximum difference from mean of observations (mm)	T	-	* See EDMI Calibration sheet following			
	L	*				
OFFICE PROCEDURES						
Triangle Closure not to exceed average	T			1.5"		
	L			1.5"		
GEODETIC LEVELLING		I/I	I/II	II/I	II/II	III
Maximum loop misclosure (mm)					5.4	

T - Triangulation
L - Traverse

(continued)

Table 8.--Concluded

EDMI calibration
Corbin Calibration Base Line

Wild DI5 Serial No. 50171

Observations and least squares adjustment performed according to NOAA Technical Memorandum NOS NGS-10.

A priori input to least squares adjustment..........	±3 mm + 2 ppm
Scale correction....................................	+3.76 ppm
Constant correction.................................	+32.7 mm
Variance of unit weight.............................	0.80 (unitless)
Standard error of scale correction..................	±2.38 ppm
Standard error of constant correction...............	±1.32 mm

Results of constant determination derived from least squares adjustment. These values were used in Corbin quad observations reduction.

APPENDIX A.--CORBIN CALIBRATION BASE LINE DATA

US DEPARTMENT OF COMMERCE - NOAA
NOS - NATIONAL GEODETIC SURVEY
ROCKVILLE MD 20852 - NOVEMBER 10, 1982

CALIBRATION BASE LINE DATA
BASE LINE DESIGNATION CORBIN
PROJECT ACCESSION NUMBER G15767

QUAD N387732
VIRGINIA
CAROLINE COUNTY

LIST OF ADJUSTED DISTANCES (AUGUST 2, 1982)

FROM STATION	ELEV (M)	TO STATION	ELEV (M)	ADJ DIST (M) HORIZONTAL	ADJ DIST (M) MARK - MARK	STD ERROR(MM)
0	66.720	50	66.910	50.0058	50.0062	0.0
0	66.720	300	65.516	300.0016	300.0040	0.2
0	66.720	500	64.055	499.9956	500.0027	0.2
0	66.720	1000	64.944	1000.0236	1000.0252	0.4
50	66.910	300	65.516	249.9958	249.9997	0.2
50	66.910	500	64.055	449.9898	449.9989	0.2
50	66.910	1000	64.944	950.0178	950.0199	0.4
300	65.516	500	64.055	199.9940	199.9994	0.1
300	65.516	1000	64.944	700.0220	700.0222	0.4
500	64.055	1000	64.944	500.0279	500.0287	0.4

DESCRIPTION OF CORBIN BASE LINE
YEAR MEASURED: 1976 - 1982
CHIEF OF PARTY: VARIOUS

THE BASE LINE IS LOCATED APPROXIMATELY 10 MILES NORTH OF BOWLING GREEN, NINE MILES SOUTH-SOUTHEAST OF FREDERICKSBURG AND 0.6 MILE EAST OF CORBIN, VIRGINIA. THE BASE LINE IS SITUATED ON U.S. GOVERNMENT PROPERTY AT THE SITE OF THE FREDERICKSBURG GEOMAGNETIC CENTER AND THE OFFICE OF THE INSTRUMENT AND EQUIPMENT BRANCH OF THE NATIONAL GEODETIC SURVEY

TO REACH THE INSTRUMENT AND EQUIPMENT BRANCH OFFICE OF THE NATIONAL GEODETIC SURVEY FROM THE JUNCTION OF U.S. HIGHWAY 17 SOUTH BYPASS AND VIRGINIA STATE HIGHWAY 2 WHICH IS APPROXIMATELY 6.5 MILES SOUTH OF FREDERICKSBURG, GO SOUTH ON STATE HIGHWAY 2 FOR 2.35 MILES TO A STORE ON THE LEFT AND A SIDE ROAD LEFT, JUST BEYOND THE STORE IN THE SMALL SETTLEMENT OF CORBIN. TURN LEFT AND GO SOUTHEAST AND EAST ON STATE HIGHWAY 610 FOR 0.4 MILE TO WHERE THE HIGHWAY BEARS SHARP LEFT AND A SECONDARY ROAD (BURMA ROAD) GOES STRAIGHT AHEAD. CONTINUE EAST ON BURMA ROAD (U.S. PROPERTY) FOR 0.3 MILE TO A CIRCLE DRIVEWAY ON THE LEFT. TURN LEFT AND GO NORTH AND EAST ON THE DRIVEWAY FOR 0.1 MILE TO THE OFFICE OF THE INSTRUMENT AND EQUIPMENT BRANCH ON THE LEFT WHERE INFORMATION CONCERNING THE LOCATION OF THE BASE LINE CAN BE OBTAINED.

THE HORIZONTAL LENGTH OF THE BASE LINE IS 1000 METERS. IT IS MONUMENTED AT 0M, 50M, 300M, 500M, 925M, AND 1000M. EACH MONUMENT IS OF POURED CONCRETE SET INTO A DEPTH OF FIVE FEET. THE MONUMENTS PROTRUDE TWO INCHES ABOVE THE GROUND SURFACE AND TAPER FROM 18 INCHES IN DIAMETER AT THE BOTTOM TO 10 INCHES SQUARE AT THE TOP. THERE IS A BRONZE DISK SET IN THE TOP OF EACH CONCRETE MONUMENT AND THE EXACT POINT IS A 0.4 MILLIMETER DIAMETER DRILLED HOLE IN THE CENTER OF THE DISKS.

EACH MONUMENT HAS OVER IT A PERMANENT FOUR LEGGED ANODIZED ALUMINUM INSTRUMENT STAND. THE STANDS ARE FITTED WITH 12 INCH CIRCULAR TRIBRACHS WITH A 3/4 INCH DIAMETER HOLE IN THEIR CENTER. THE TRIBRACHS ARE ADJUSTABLE FOR COLLIMATING PURPOSES. EACH POINT ON THE BASE LINE IS VISIBLE FROM ANY OTHER POINT ON THE BASE. EACH POINT CAN BE DRIVEN TO IN ANY TWO-WHEEL DRIVE VEHICLE IN ANY WEATHER.

CORBIN BASE LINE WAS ESTABLISHED PRIMARILY FOR USE BY THE NATIONAL GEODETIC SURVEY FOR THE CALIBRATION AND TESTING OF ELECTRONIC DISTANCE MEASURING INSTRUMENTS. ARRANGEMENTS FOR USE OF THE BASE LINE CAN BE MADE BY CONTACTING: WILLIAM V. MAST OR CHARLES C. GLOVER, INSTRUMENT AND EQUIPMENT BRANCH, NATIONAL GEODETIC SURVEY, NATIONAL OCEAN SURVEY, NOAA, P.O. BOX 1, CORBIN, VIRGINIA 22446. PHONE: COMMERCIAL NO. (703) 373-7605 OR FTS NO. (925) 0243-0244.

APPENDIX B.--EXAMPLE OUTPUT OF DATA LOGGING PROGRAMS

CORBIN CALIBRATION BASELINE OBSERVATIONS

FILENAME:K503-1 DATE:10/01/85

EDMI		REFLECTOR	SCALES
COMPANY:KERN	LIGHT:INFRARED	TYPE:KERN	PPM TEMP:C
MODEL:DM503	GROUP VEL:105.80	S/N:1	WET/DRY TEMP:F
S/N: 325882	PSET INDEX:281.94	CONST: 0.0000	PRESSURE:FT
MOUNT:THEO	INST.CONST: 0.0000	NO.SHOWN: 1	
S/N: 345381	REJ.TOL: 0.0050m		OBS:KL REC:CCG
W/: 0.8600 rm	FM: 14985400 Hz		

EDMI STATION		REFLECTOR STATION		
CORBIN BASE	0	CORBIN BASE	50	HUMIDITY
HT ABOVE TRI:	0.2370	HT ABOVE TRI:	0.2370	D/B TEMP: 74.0
HT OF STAND:	1.8060	HT OF STAND:	1.1560	W/B TEMP: 66.0
ELEV OF MARK:	66.7203	ELEV OF MARK:	66.9106	H CORR: 0.7
ELEV EDMI:	66.7633	ELEV OF REFL:	68.3636	SETS OF OBS: 4

START TIME:	113126	113553	113938	114310
END TIME:	113353	113802	114136	114511
1	50.005	49.857	50.158	50.008
2	50.009	49.856	50.157	50.007
3	50.010	49.858	50.157	50.007
4	50.009	49.857	50.158	50.007
5	50.010	49.857	50.158	50.008
6	50.010	49.857	50.157	50.007
7	50.010	49.857	50.159	50.007
8	50.011	49.857	50.157	50.007
9	50.010	49.857	50.157	50.007
10	50.009	49.858	50.157	50.007
MN SLP DIST:	50.0093	49.8571	50.1575	50.0072
REFL ECC:	0.0000	0.1500	-0.1500	0.0000
SUM:	50.0093	50.0071	50.0075	50.0072
REFL CONST:	0.0000	0.0000	0.0000	0.0000
R.I. CORR:	0.0006	0.0006	0.0006	0.0006
CORR SL DIST:	50.0099	50.0077	50.0081	50.0078
MET DATA:	TEMP/PRES	TEMP/PRES.	TEMP/PRES	TEMP/PRES
EDMI BEGIN:	22.7 /1060.0	23.3 /1060.0	23.4 /1060.0	24.0 /1060.0
REFL BEGIN:	22.0 /1040.0	22.3 /1035.0	22.5 /1035.0	22.8 /1040.0
EDMI END:	22.8 /1060.0	23.2 /1060.0	24.0 /1060.0	24.2 /1060.0
REFL END:	22.6 /1040.0	22.9 /1035.0	23.4 /1040.0	22.4 /1040.0
MEAN:	23.53 /1050.0	22.93 /1047.5	23.33 /1048.8	23.35 /1050.0
MN PRES (mmHG):	758.0	758.1	758.1	758.0

MN CORR SL DIST: 50.0084

- EDMI HOZ DIST: 50.0060
- BASE HOZ DIST: 50.0050
- DIF(EDMI-BASE): 0.0010

REMARKS:NONE

TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: QWIL1 DATE:12/05/85

INSTRUMENT INFORMATION

MANUFACTURER: WILD	EDMI MODEL NAME: DI5
MODEL: T2000	SERIAL NUMBER: 50171
SERIAL NUMBER: 388310	EDMI OFFSET CONST: 0.0328

TEMP & PRES SCALE UNITS	PERSONNEL
PPM TEMP SCALE: C	OBSERVER: CCG
WET/DRY TEMP SCALE: F	RECORDER: KD
PRESSURE SCALE: FT	

STANDPOINT INFORMATION

SPN: 4	MARK ELEVATION: 67.66600
NAME: CORBIN QUAD 4	HT OF TRI ABOVE MK: 1.6132
	HT OF INST ABOVE TRI: 0.2338
	ELEV OF INST: 69.51300

3 FOREPOINTS OBSERVED WX START:00021 WX END:00028

FOREPOINT NO. 1 INFORMATION

SPN: 1	MARK ELEVATION: 66.62160
NAME: CORBIN QUAD 1	HT OF TRI ABOVE MK: 1.5153
REFL TYPE: HUTSON	HT OF REFL ABOVE TRI: 0.1768
REFL S/N: 33-85	
REFL OFFSET CONST: -.0531	ELEV OF REFL: 68.31370
NO. PRISMS SHN: 1	

FOREPOINT NO. 2 INFORMATION

SPN: 2	MARK ELEVATION: 67.57140
NAME: CORBIN QUAD 2	HT OF TRI ABOVE MK: 1.5370
REFL TYPE: HUTSON	HT OF REFL ABOVE TRI: 0.1786
REFL S/N: 35-85	
REFL OFFSET CONST: -.0530	ELEV OF REFL: 69.28700
NO. PRISMS SHN: 1	

FOREPOINT NO. 3 INFORMATION

SPN: 3	MARK ELEVATION: 68.61040
NAME: CORBIN QUAD 3	HT OF TRI ABOVE MK: 1.6191
REFL TYPE: HUTSON	HT OF REFL ABOVE TRI: 0.1800
REFL S/N: 34-85	
REFL OFFSET CONST: -.0530	ELEV OF REFL: 70.40950
NO. PRISMS SHN: 1	

FILENAME: QWIL1 DATE:12/05/85

HORIZONTAL DIRECTIONS

STANDPOINT: CORBIN QUAD 4

POS	FOREPOINT	D/R	OBS'D DIR (DDD.MMSSS)	COL (SS.S)	DIRECTION (DDD.MMSSS)	TIME
1	CORBIN QUAD 1	D	0.00200			START: 10:30
		R	180.00196	+0.4		END: 10:39
	CORBIN QUAD 2	D	39.18561			
		R	219.18555	+0.6	39.18360	
	CORBIN QUAD 3	D	77.56231			
		R	257.56227	+0.4	77.56031	

REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV

POS	FOREPOINT	D/R	OBS'D DIR (DDD.MMSSS)	COL (SS.S)	DIRECTION (DDD.MMSSS)	TIME
2	CORBIN QUAD 1	D	11.00220			START: 10:41
		R	191.00199	+2.1		END: 10:48
	CORBIN QUAD 2	D	50.18571			
		R	230.18566	+0.5	39.18359	
	CORBIN QUAD 3	D	88.56259			
		R	268.56248	+1.1	77.56044	

REMARKS:
NONE

POS	FOREPOINT	D/R	OBS'D DIR (DDD.MMSSS)	COL (SS.S)	DIRECTION (DDD.MMSSS)	TIME
3	CORBIN QUAD 1	D	22.00250			START: 10:48
		R	202.00257	-0.7		END: 10:55
	CORBIN QUAD 2	D	61.19019			
		R	241.19015	+0.4	39.18364	
	CORBIN QUAD 3	D	99.56291			
		R	279.56288	+0.3	77.56036	

REMARKS:
NONE

POS	FOREPOINT	D/R	OBS'D DIR (DDD.MMSSS)	COL (SS.S)	DIRECTION (DDD.MMSSS)	TIME
4	CORBIN QUAD 1	D	33.00321			START: 10:55
		R	213.00300	+2.1		END: 11:01
	CORBIN QUAD 2	D	72.19066			
		R	252.19069	-0.3	39.18357	
	CORBIN QUAD 3	D	110.56362			
		R	290.56343	+1.9	77.56042	

REMARKS:
GPS VEHICLE WITH MOTOR RUNNING CAUSES SCINTILLATION ON LINE TO CQ3

TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: QWIL1 DATE:12/05/85

ABSTRACT OF HORIZONTAL DIRECTIONS

STANDPOINT: CORBIN QUAD 4

FOREPOINTS OBSERVED

POS	(INITIAL) CORBIN QUAD 1 (DDD.MMSSS)	CORBIN QUAD 2 (DDD.MMSSS)	CORBIN QUAD 3 (DDD.MMSSS)
1	000.00000	39.18360	77.56031
2	000.00000	39.18359	77.56044
3	000.00000	39.18364	77.56036
4	000.00000	39.18357	77.56042
5	000.00000	39.18350	77.56034
6	000.00000	39.18350	77.56035
7	000.00000	39.18350	77.56027
8	000.00000	39.18346	77.56013
9	000.00000	39.18345	77.56034
10	000.00000	39.18358	77.56037
11	000.00000	39.18354	77.56006
12	000.00000	39.18353	77.56028
13	000.00000	39.18348	77.56024
14	000.00000	39.18374	77.56034
15	000.00000	39.18361	77.56051
16	000.00000	39.18353	77.56029

MEAN DIRECTION	39.183549	77.560313
STANDARD DEVIATION	0.000075	0.000110

TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: OWIL1 DATE: 12/05/85

FIELDBOOK & ABS OF ZENITH DISTANCES

STANDPOINT: CORBIN QUAD 4 ELEV: 69.51300

POS	FOREPOINT	D/R	OBS'D ZD	SUM D/R	CORR'D ZD	TIME
1			DDD.MMSSS	DDD.MMSSS	DDD.MMSSS	10:30
	CORBIN QUAD 1	D	90.28234			
	EL RFL: 68.31370	R	269.33203	360.01437	90.27316	
	CORBIN QUAD 2	D	90.04470			
	EL RFL: 69.28700	R	269.56359	360.01229	90.04056	
	CORBIN QUAD 3	D	89.36492			
	EL RFL: 70.40950	R	270.25131	360.02023	89.35481	

REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV

POS	FOREPOINT	D/R	OBS'D ZD	SUM D/R	CORR'D ZD	TIME
2			DDD.MMSSS	DDD.MMSSS	DDD.MMSSS	10:41
	CORBIN QUAD 1	D	90.28243			
	EL RFL: 68.31370	R	269.33196	360.01439	90.27324	
	CORBIN QUAD 2	D	90.04475			
	EL RFL: 69.28700	R	269.56384	360.01259	90.04046	
	CORBIN QUAD 3	D	89.36500			
	EL RFL: 70.40950	R	270.25158	360.02058	89.35471	

REMARKS:
NONE

POS	FOREPOINT	D/R	OBS'D ZD	SUM D/R	CORR'D ZD	TIME
3			DDD.MMSSS	DDD.MMSSS	DDD.MMSSS	10:48
	CORBIN QUAD 1	D	90.28233			
	EL RFL: 68.31370	R	269.33209	360.01442	90.27312	
	CORBIN QUAD 2	D	90.04453			
	EL RFL: 69.28700	R	269.56349	360.01202	90.04052	
	CORBIN QUAD 3	D	89.36508			
	EL RFL: 70.40950	R	270.25139	360.02047	89.35485	

REMARKS:
NONE

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FILENAME: QWIL1 DATE: 12/05/85

MEAN CORRECTED ZENITH DISTANCES

STANDPOINT: CORBIN QUAD 4

FOREPOINTS OBSERVED

POS	CORBIN QUAD 1	CORBIN QUAD 2	CORBIN QUAD 3
	DDD.MMSSS	DDD.MMSSS	DDD.MMSSS
1	90.27316	90.04056	89.35481
2	90.27324	90.04046	89.35471
3	90.27312	90.04052	89.35485
4	90.27330	90.04071	89.35467
5	90.27324	90.04060	89.35489
6	90.27324	90.04057	89.35476
7	90.27330	90.04069	89.35469
8	90.27337	90.04093	89.35468
9	90.27333	90.04066	89.35500
10	90.27319	90.04052	89.35493
11	90.27329	90.04057	89.35470
12	90.27342	90.04068	89.35486
13	90.27327	90.04046	89.35478
14	90.27328	90.04051	89.35491
15	90.27324	90.04067	89.35494
16	90.27324	90.04056	89.35475
MEAN:	90.27326	90.04060	89.35481
STD DEV:	0.00008	0.00012	0.00011

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```
FILENAME: OWILI                                                    DATE: 12/05/85
*********************************************************************************
                     SUMMARY OF CORRECTED SLOPE DISTANCES
*********************************************************************************
STANDPOINT: CORBIN QUAD 4   * OBS: CCB  REC: KD  * WX-BEGIN: 00021  END: 00020
---------------------------------------------------------------------------------
TEMP-WET:  33.5  DRY:  37.0 * HUMIDITY CORR: 0.2 * EDMI CONST: 0.0328
*********************************************************************************
 POS  1 *             (BEGIN)              *                (END)
=================================================================================
        *  TIME       TEMP      PRES     *   TIME       TEMP       PRES
---------------------------------------------------------------------------------
        *  10:30      3.8       870      *   10:39      4.0        870
=================================================================================
     FOREPOINT        * D/R * OBS S/D   * MN OBS'D *  PPM   * RI COR  * CORR'D S/D
=================================================================================
CORBIN QUAD 1         *  D  * 150.0260 *            *        *         *
REFL CONST: -.0531    *  R  * 150.0250 * 150.0255 *  -8.8  * -.0013 * 150.0039
---------------------------------------------------------------------------------
CORBIN QUAD 2         *  D  * 193.9150 *            *        *         *
REFL CONST: -.0530    *  R  * 193.9150 * 193.9150 *  -8.8  * -.0017 * 193.8931
---------------------------------------------------------------------------------
CORBIN QUAD 3         *  D  * 127.2560 *            *        *         *
REFL CONST: -.0538    *  R  * 127.2560 * 127.2560 *  -8.8  * -.0011 * 127.2339
---------------------------------------------------------------------------------
REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV
*********************************************************************************
 POS  2 *             (BEGIN)              *                (END)
=================================================================================
        *  TIME       TEMP      PRES     *   TIME       TEMP       PRES
---------------------------------------------------------------------------------
        *  10:41      4.1       870      *   10:48      3.9        870
=================================================================================
     FOREPOINT        * D/R * OBS S/D   * MN OBS'D *  PPM   * RI COR  * CORR'D S/D
=================================================================================
CORBIN QUAD 1         *  D  * 150.0260 *            *        *         *
REFL CONST: -.0531    *  R  * 150.0250 * 150.0255 *  -8.7  * -.0013 * 150.0039
---------------------------------------------------------------------------------
CORBIN QUAD 2         *  D  * 193.9150 *            *        *         *
REFL CONST: -.0530    *  R  * 193.9140 * 193.9145 *  -8.7  * -.0017 * 193.8926
---------------------------------------------------------------------------------
CORBIN QUAD 3         *  D  * 127.2570 *            *        *         *
REFL CONST: -.0538    *  R  * 127.2550 * 127.2560 *  -8.7  * -.0011 * 127.2339
---------------------------------------------------------------------------------
REMARKS:
NONE
*********************************************************************************

                                   PAGE  1
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FILENAME: OWIL1 DATE: 12/05/85

MEAN CORRECTED SLOPE DISTANCES

STANDPOINT: CORBIN QUAD 4

FOREPOINTS OBSERVED

POS	CORBIN QUAD 1	CORBIN QUAD 2	CORBIN QUAD 3
1	150.0039	193.8931	127.2339
2	150.0039	193.8926	127.2339
3	150.0029	193.8931	127.2339
4	150.0049	193.8922	127.2334
5	150.0040	193.8927	127.2329
6	150.0035	193.8922	127.2335
7	150.0040	193.8922	127.2350
8	150.0040	193.8928	127.2340
9	150.0047	193.8921	127.2337
10	150.0034	193.8927	127.2343
11	150.0038	193.8917	127.2338
12	150.0033	193.8916	127.2337
13	150.0048	193.8926	127.2337
14	150.0048	193.8917	127.2333
15	150.0048	193.8932	127.2338
16	150.0033	193.8922	127.2343
MEAN:	150.0040	193.8924	127.2338
STD DEV:	0.0006	0.0005	0.0005
HOZ DIST:	149.9992	193.8923	127.2306
GEO DIST:	149.9976	193.8902	127.2292

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TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: OWIL1 DATE: 12/05/85

FIELDBOOK OF ELEVATION DIFFERENCES

STANDPOINT: CORBIN QUAD 4 • EL EDM: 69.51300 • TIME-BGN: 10:30 END: 14:14

POS	FOREPOINT	D/R	OBS'D EL DIFF	MN D/R OBS'D	KWN EL DIFF
1					
	CORBIN QUAD 1	D	-1.237		
	EL RFL: 68.31370	R	-1.162	-1.1995	-1.19930
	CORBIN QUAD 2	D	-0.267		
	EL RFL: 69.28700	R	-0.189	-0.2280	-0.22600
	CORBIN QUAD 3	D	0.859		
	EL RFL: 70.40950	R	0.935	0.8970	0.89650

REMARKS:
PERFECT OBSERVING CONDITIONS-OBS TOP TGT @ DIR AND BOT TGT @ REV

POS	FOREPOINT	D/R	OBS'D EL DIFF	MN D/R OBS'D	KWN EL DIFF
2					
	CORBIN QUAD 1	D	-1.238		
	EL RFL: 68.31370	R	-1.162	-1.2000	-1.19930
	CORBIN QUAD 2	D	-0.267		
	EL RFL: 69.28700	R	-0.187	-0.2270	-0.22600
	CORBIN QUAD 3	D	0.859		
	EL RFL: 70.40950	R	0.936	0.8975	0.89650

REMARKS:
NONE

POS	FOREPOINT	D/R	OBS'D EL DIFF	MN D/R OBS'D	KWN EL DIFF
3					
	CORBIN QUAD 1	D	-1.241		
	EL RFL: 68.31370	R	-1.162	-1.2015	-1.19930
	CORBIN QUAD 2	D	-0.265		
	EL RFL: 69.28700	R	-0.190	-0.2275	-0.22600
	CORBIN QUAD 3	D	0.858		
	EL RFL: 70.40950	R	0.935	0.8965	0.89650

REMARKS:
NONE

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TOTAL STATIONS TEST - FIELDBOOK OF OBSERVATIONS

FILENAME: QWIL1 DATE:12/05/85

FIELDBOOK OF ELEVATION DIFFERENCES

STANDPOINT: CORBIN QUAD 4 * EL EDM: 69.51300 * TIME-BGN:10:30 END:14:14

FOREPOINTS OBSERVED

	CORBIN QUAD 1		CORBIN QUAD 2		CORBIN QUAD 3	
	EL RFL: 68.31370		EL RFL: 69.28700		EL RFL: 70.40950	
KWN	EL DIF: -1.19930		EL DIF: -0.22600		EL DIF: 0.89650	
POS	MN OBSD (meters)	OBS-KWN (mm)	MN OBSD (meters)	OBS-KWN (mm)	MN OBSD (meters)	OBS-KWN (mm)
1	-1.1995	-0.2	-0.2280	-2.0	0.8970	0.5
2	-1.2000	-0.7	-0.2270	-1.0	0.8975	1.0
3	-1.2015	-2.2	-0.2275	-1.5	0.8965	0.0
4	-1.2005	-1.2	-0.2295	-3.5	0.8980	1.5
5	-1.2005	-1.2	-0.2285	-2.5	0.8965	0.0
6	-1.2005	-1.2	-0.2280	-2.0	0.8970	0.5
7	-1.2010	-1.7	-0.2295	-3.5	0.8975	1.0
8	-1.2005	-1.2	-0.2315	-5.5	0.8975	1.0
9	-1.2010	-1.7	-0.2285	-2.5	0.8960	-0.5
10	-1.1995	-0.2	-0.2275	-1.5	0.8960	-0.5
11	-1.2010	-1.7	-0.2280	-2.0	0.8980	1.5
12	-1.2005	-1.2	-0.2290	-3.0	0.8970	0.5
13	-1.2000	-0.7	-0.2275	-1.5	0.8970	0.5
14	-1.2005	-1.2	-0.2275	-1.5	0.8965	0.0
15	-1.2005	-1.2	-0.2295	-3.5	0.8960	-0.5
16	-1.2005	-1.2	-0.2280	-2.0	0.8975	1.0

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