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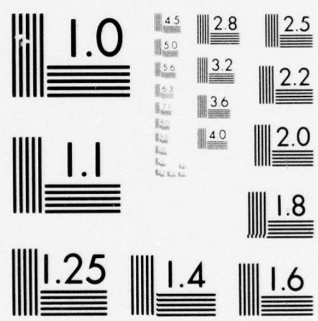

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PLATFORM ORIENTATION SYSTEM TEST PROGRAM

November 1976

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U.S. ARMY ENGINEER
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Forward Observer Vehicle (FOV)
Platform Orientation System (POS)-406
Flux-gate Compass

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

This report discusses a limited field test performed on the POS (Platform Orientation System)-406. The function of the POS-406 is to provide a grid, true, or magnetic north reference to ground vehicles. The objective of this test program was to evaluate a magnetic type of north-seeker as the north reference in future FOV (Forward Observer Vehicle) development. Based upon the analysis of data obtained in this test, future FOV planning and development should include both magnetic and gyrocompass types of north references.

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PREFACE

The test and evaluation described in this report was accomplished under the authority of project 1S764716D578, Field Army Surveying Equipment; Task 29, Work Unit 0002, Forward Observer Vehicle Kit.

The work on this report was accomplished by Glenn W. Schmeidel under the supervision of Milton Goldin, Chief, Electronics Surveying Branch and Carl R. Friberg, Jr., Chief, Surveying and Engineering Division, U.S. Army Engineer Topographic Laboratories (USAETL). Technical support was provided by Pierre J. Gauthier and Bob Wright of Aviation Electric, Ltd., Montreal, Canada.

TABLE OF CONTENTS

ILLUSTRATIONS

PLATFORM ORIENTATION SYSTEM TEST PROGRAM

INTRODUCTION

Scope. This report covers a limited field test of a magnetic heading device mounted on an M113A1 armored personnel carrier.

Background. The POS-406 was developed by Aviation Electric, Ltd. (AEL), Montreal, Quebec, Canada. This company is a division of the Bendix Corporation. The POS-406 was initially designed for ground to air mobile fire-units, where minimum time to obtain heading is of prime importance. A need to develop the alternative technical approaches for a Forward Observer Vehicle (FOV) Kit led the U.S. Army Engineer Topographic Laboratories (ETL) to evaluate a compensated magnetic north seeker as a possible method of establishing the north grid reference for the FOV. At the present time gyroscopic north seekers provide the only viable north orienting devices consistent with the FOV mission.

During the October to December 1975 time period, a test bed FOV armored personnel carrier, M113A1 was used to test the operational conceptual feasibility of an FOV. During this test, conducted by Modern Army Selected Systems Test Evaluation and Review (MASSTER), the performance of the POS-406 appeared to have potential for satisfying the FOV mission. Based on this observation, ETL planned a special POS-406 test to be conducted during January 1976. The POS-406 test, with support of MASSTER and AEL personnel was started on 14 January 1976. Failure of the M113A1 drive train (transmission and engine) resulted in termination of the test on 19 January 1976.

Program Objective. The overall objective of this test program was to evaluate the Platform Orientation System, (POS-406), for application as a north orienting reference in future FOV development.

INVESTIGATION

Test Item Description. The POS-406 consists of two components, the Magnetic Unit (MU) and the Indicator & Control Unit (ICU) interconnected with a cable. The MU was mounted on the right rear corner of the vehicle roof, and the ICU was mounted on the left inside vehicle wall (see figures 1 and 2). The equipment required an external 24-watt, 24-volt d.c. (VDC) power source. The characteristics of the POS-406 are as specified in table 1.

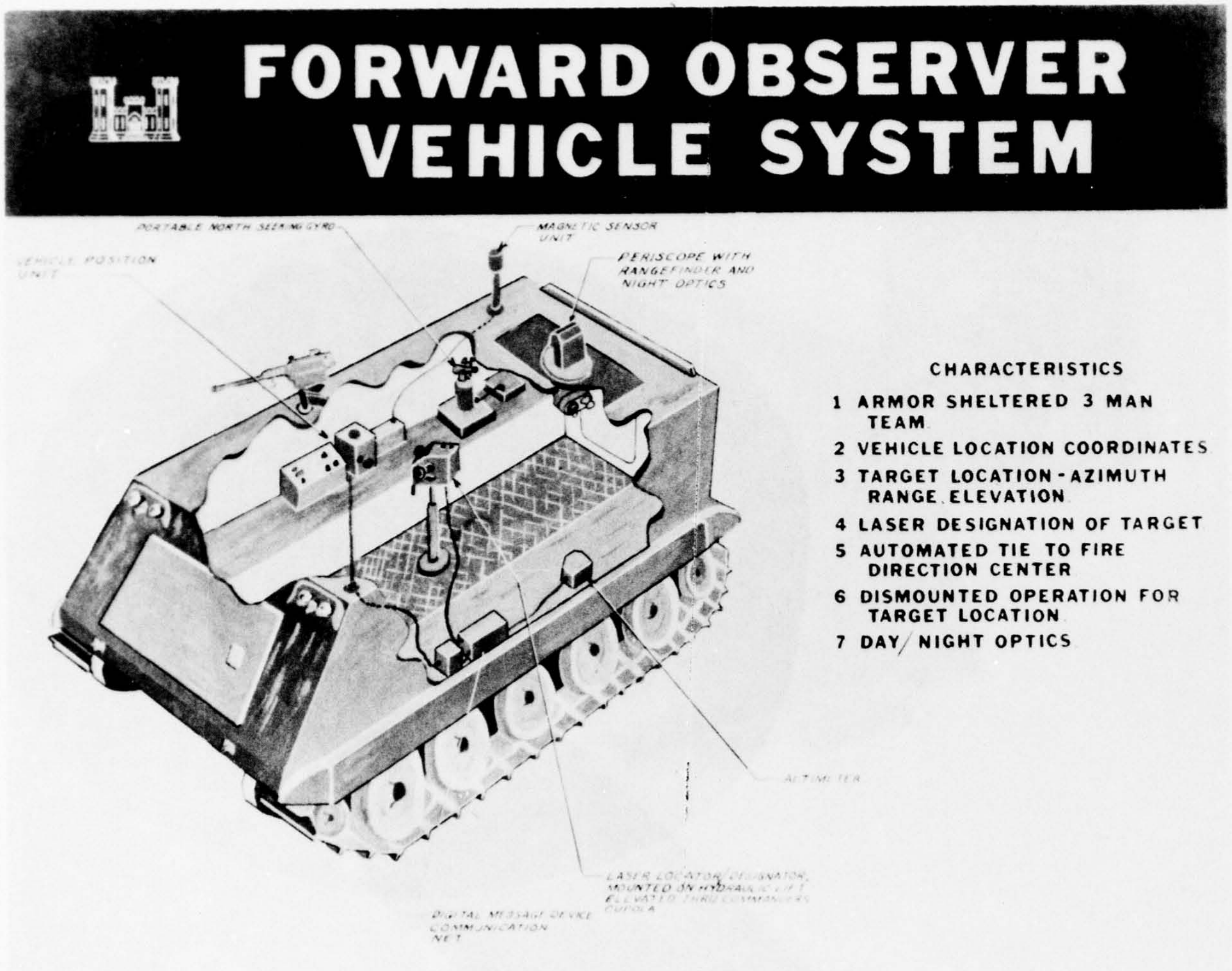

Figure 1. FOV Concept.

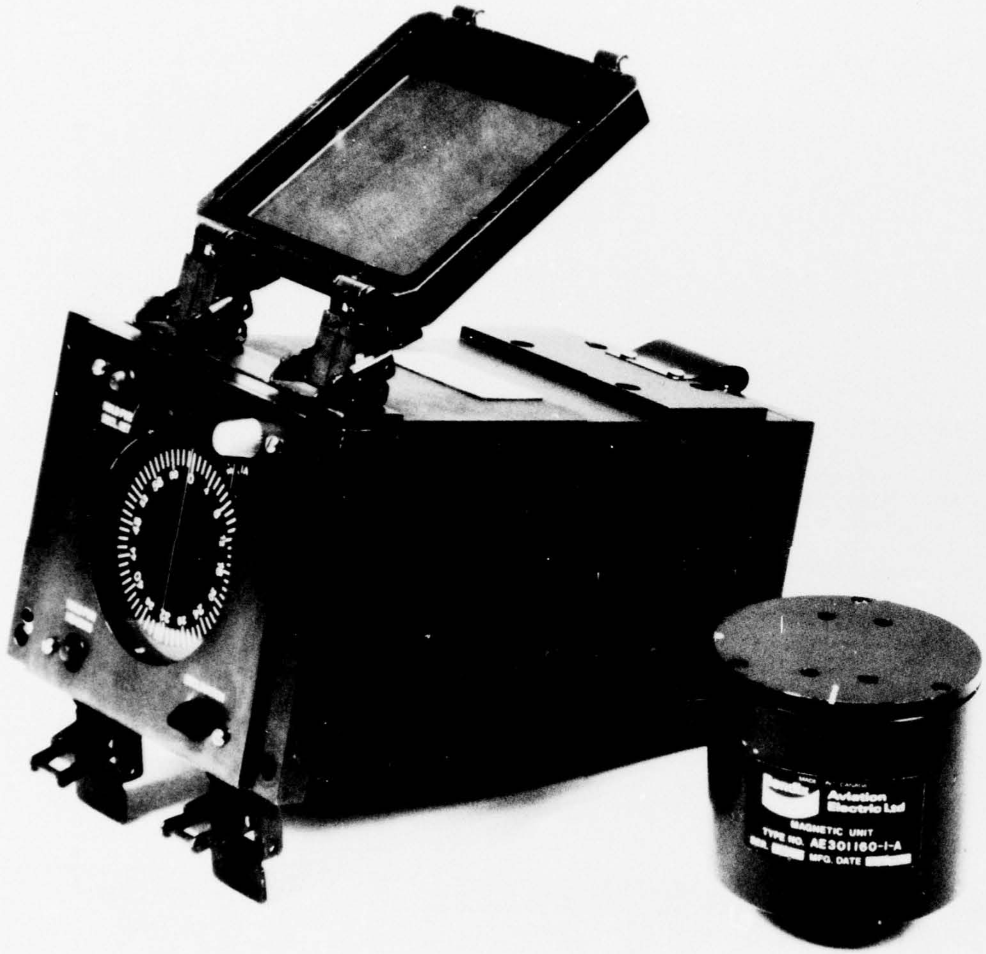

Figure 2. POS-406 Components.

Table 1. POS-406 Characteristics

<u>Magnetic Unit</u>.	
Size:	
Diameter	8.9 cm (3 1/2 in)
Length	9.2 cm (3 5/8 in)
Weight	1.0 kg (2 1/4 lb)
<u>Indicator & Control Unit</u>.	
Readout Resolution	2 mils/div
Adjustable North Reference	Adjustable to grid, true, or magnetic north
Declination Control	0-533 mils east or west
Size:	
Width	14.2 cm (5.58 in)
Height	15.3 cm (6.01 in)
Depth	26.2 cm (10.3 in)
Weight	5.1 kg (11 1/4 lb)
D.C. Power	24.0 watts (@ 24 VDC Nom)

<u>Principle of Operation</u>. The POS-406 is a compensated flux-gate compass. The Magnetic Unit (MU) normally mounted on the exterior of the user vehicle contains a pendulously supported sealed flux-gate magnetic sensor. The Indicator & Control Unit (ICU) contains a twin dial display and magnetic compensation circuits. Automatic readout is optional through the provision of three electrically independent synchro devices. A declination control on the indicator panel of the ICU permits referencing the vehicle heading to grid, true, or magnetic north.

The basic flux-gate is the Bendix or General Electric aircraft instrument, which has an accuracy between 0.5 and 2 degrees. This type of instrument, particularly when mounted in a vehicle that contains significant masses of magnetic material, exhibits an error curve having a dominant fundamental and a less dominant first harmonic as the major component sine waves over the 360° period of vehicle rotation (i.e. when plotted as a function of vehicle heading).

The compensation technique, as applied in the horizontal plane, consists of summing the output of two function generators, which generate the negative of the above fundamental and first harmonic error components and minimizing the error of the above error curve by amplitude summation. Proprietary techniques are also applied toward minimizing the harmonic components existing in the vertical field.

The POS-406, mounted in the user vehicle, is compensated by moving the vehicle through 360° in 45° increments, measuring and recording the indication of north at each stopping point. The measured errors are then processed through a computer smoothing program. This process determines the individual function generator settings required to minimize the total uncompensated error over a full circle of vehicle travel. The vehicle is then moved through a second rotation to check the function generator settings. The POS-406, thus compensated, does not need to be compensated again, unless changes in vehicle configuration occur.

Test Facilities.

Test Sites. Test circles 10 meters in diameter located at Fort Hood, Texas were selected at random (see figure 3). These circles were circumscribed about centers located on the following approximated UTM coordinates and along the following reference azimuth (table 2):

Table 2. Test Site Locations

Area Circle or Ref. Point	*Declination Correction (Mils)	Easting (Kilometers)	Northing (Kilometers)	***Reference Azimuth (Mils) Grid N.
1a	-0.31	613xx	3451xx	3098.34
1b	-0.31	613xx	3451xx	3092.10
2	1.14	604xx	3451xx	2113.84
3	0	606xx	3459xx	2596.96
4	0	611xx	3459xx	2931.37
5		612xx	3463xx	
6	+3.17	616xx	3457xx	3253.22
Reference Circle		60934	345196	2439.35
**W. Tower (Ref. Point)		61547	344533	

* Magnetometer readings were taken at each area to determine local corrections in the map specified declination of 142 mils.

** W. tower was used as the distant point for all test circles except area 1a and 1b.

*** Azimuths as measured using FRALINE.

Test Support. The test support from Headquarters, MASSTER, Fort Hood consisted of the M113A1 test vehicle, a driver, a vehicle commander, a survey team of 2, and the auxiliary support items, such as fuel, vehicle maintenance, a roll of barbed wire, etc.

The Fast Reaction Automatic Lightweight Inertial Northseeking Equip-

Figure 3. Map of Fort Hood.

ment (FRALINE) used for measuring the various reference azimuths was provided by Lear Seigler, Inc.

Field Test Procedure.

Purpose. The purpose of the field test was to compare the POS-406 heading measurements on the M113A1 vehicle under various configurations and in random areas of operation against standard survey methods.

Method. The method of testing consisted of driving the M113A1 vehicle around 10-meter diameter test circles and measuring the vehicle heading at 30° interval stop points.

The 30° intervals were determined by the vehicle driver as he monitored the directional gyro readout dial. At each 30° interval, a roof-mounted theodolite would be rotated through the angle necessary to re-sight on a specific 10-kilometer-distant reference point. The azimuth of a line through the center of the test circle and through the distant reference point was initially measured with the FRALINE (see Test Support section), which provided a north reference for the vehicle. The POS-406 control knob was adjusted to provide 142 mils declination to reference grid north rather than magnetic north.

The heading measuring instruments were mounted on the vehicle as follows:

Item	Vehicle Mounting Location
1. POS-406 - MU	Right-rear corner of roof
2. POS-406 - ICU	Left-inside wall vehicle center
3. Theodolite tripod	Directly above commanders hatch
4. LNS directional gyro	Left-inside wall forward of vehicle center

This instrumentation was used throughout the tests: (1) the variable load test, and (2) the random area test.

The Variable Load Test - This test consisted of measuring the change in POS-406 heading as the vehicle magnetic field was changed through each of the following routines at each 30° interval stop:

1. Vehicle normal (ramp closed)
2. Vehicle with helmets introduced
3. Vehicle with barbed wire on roof
4. Vehicle with ramp open
5. Vehicle back to normal (ramp closed)

This test was conducted at the reference circle where the POS-406 calibration runs took place. The reference azimuth line extended from the center of this circle (see table 2 for location) to the water tower, known as west tank, located at 9.03 kilometers away and at an azimuth of 2,439.35 mils from grid north.

The test circle introduces a theodolite measurement error owing to the vehicle being offset from the center of the circle from which the azimuth is measured (see figure 4). At the reference circle, the offset error would be $\tan^{-1}(5 \div 9{,}030) = 0.56$ mils maximum.

Random Area Test - This test, consisting of measured test circles as described above, was done at random sites with the vehicle always in the normal configuration (ramp closed). The FRALINE was used to determine the reference azimuths, and the range was determined from the map and from the AN/GVS-5 laser range finder.

Although the theodolite was the intended standard for all of the POS comparisons, vehicle breakdowns and repairs took up many of the daylight hours required for theodolite use. Therefore, random area tests were, also conducted during the evening hours using the LNS directional gyro only as the standard. The gyro has a readout resolution of 0.1° per division permitting an interpolated accuracy within ± 0.025° (or ± 0.44 mils), and an apparent gyro drift rate of 0.2° per hours.

Test Results. The reduced test results for the variable load and the random area tests appear in tables 3 and 4, respectively. The tabulated data, as collected during the test period, and a theodolite verification test appear in tables A1, A2, and A3 of the appendix.

The error columns in tables 3 and 4 were obtained by translating each of the columns of theodolite data (see tables A1 and A2), such that they began with a zero heading. This was accomplished by subtracting each theodolite reading in any given column from the first reading of that column. Finally, the theodolite value (or gyro value, when referenced) was subtracted from the respective POS-406 value for each point of that particular test circle. After the main data gathering period, an auxiliary test was conducted to help evaluate the effects of vehicle vibration along with other effects (see table A3, appendix).

DISCUSSION

Evaluation of Variable Load Test Results. The results of the variable load test, table 3, indicate that the half-range error of each column (R/2) is ± 5.8 mils or less for all variable loads, except in the cases where barbed wire is introduced. In the barbed wire cases, the half-range error is increased to ± 11.3 mils.

The mean, $\bar{x}$, is seen to be 5.8 mils or less for all columns. The barbed wire cases present a smaller value of $\bar{x}$, that of 4.6 mils in run

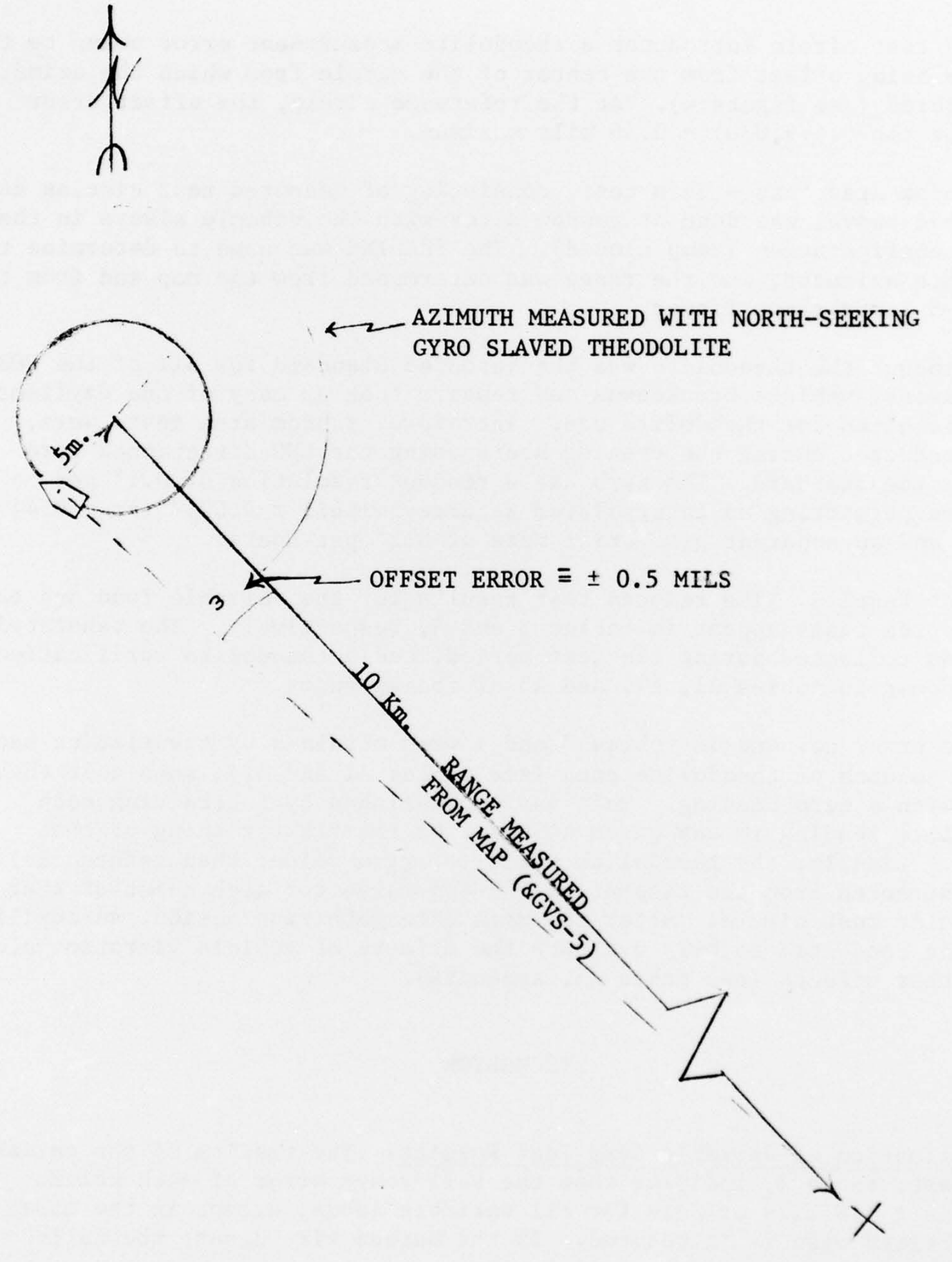

Figure 4. Typical Test Circle.

Table 3. Variable Load Test Results

INTERVAL DEGREES	POS-406 MINUS THEODOLITE ERROR (MILS)							
	RUN NO. 1					RUN NO. 2		
	VEHICLE NORMAL	VEHICLE W/HEL-METS	VEHICLE W/BARB WIRE	VEHICLE W/RAMP OPEN	VEHICLE BACK TO NORMAL	VEHICLE NORMAL	VEHICLE W/BARB WIRE	VEHICLE BACK TO NORMAL
0	0	0	-5.0	-1.0	0	6.0	7.0	6.0
30	6.2	6.2	10.2	4.2	6.2	6.9	4.9	6.9
60	4.9	4.9	6.9	1.9	4.9	7.9	8.9	7.9
90	8.6	8.6	9.6	8.6	9.6	8.5	5.5	8.5
120	4.6	5.6	-1.4	4.6	5.6	5.4	.4	4.4
150	3.6	3.6	5.6	5.6	4.6	1.3	-13.7	1.3
180	8.6	7.6	8.6	10.6	7.6	5.1	-8.9	4.1
210	9.8	8.8	9.8	8.8	8.8	5.7	-10.3	5.7
240	7.8	7.8	6.8	8.8	7.8	4.6	7.3	4.6
270	4.1	4.1	- .9	3.1	5.1	6.8	2.8	6.8
300	5.1	4.1	-5.9	3.1	5.1	9.0	4.0	10.0
330	-1.0	-1.0	2.0	-1.0	-2.0	4.4	-2.6	4.4
360	4.5	4.5	13.5	2.5	5.5	4.4	-4.6	4.4
±R/2	5.4	4.9	9.7	5.8	5.8	3.9	11.3	4.4
$\bar{x}$	5.1	5.0	4.6	4.6	5.3	5.8	0	5.8
σ	3.2	3.0	6.2	3.7	3.2	2.1	7.4	2.3
RMS	6.0	5.2	7.5	5.0	6.1	6.2	7.4	6.2

±R/2 - STATISTICAL RANGE ÷ 2
$\bar{x}$ ---- ARITHMETIC MEAN
σ ---- STANDARD DEVIATION
RMS -- ROOT MEAN SQUARE

Table 4. Random Area Test Results

INTERVAL DEGREES	RUN NO. 1		RUN NO. 2		RUN NO. 3		
	AREA 1b		REF. CIR.	AREA 2	AREA 1a		AREA 1b
	POS-GYRO	POS-THEO	POS-GYRO	POS-GYRO	POS-GYRO	POS-THEO	POS-GYRO
0	10.0	5.9	5.0	7.0	6.0	6.0	6.0
30	0.7	13.7	8.7	11.7	3.7	5.2	5.7
60	4.3	8.8	10.3	9.3	4.3	0.1	5.3
90	11.0	14.8	9.0	9.0	0.	4.6	9.0
120	13.7	14.3	7.7	8.7	9.7	3.9	7.7
150	13.3	13.0	8.3	11.3	11.3	9.2	6.3
180	13.0	14.0	5.0	11.0	13.0	9.4	6.0
210	9.7	15.6	3.7	4.7	12.7	9.9	7.7
240	3.3	10.1	5.3	4.3	7.3	7.4	3.3
270	9.0	14.1	2.0	3.0	10.0	7.8	7.0
300	8.7	9.2	-0.3	0.7	6.7	5.4	2.7
330	8.3	9.3	-0.7	2.3	7.3	3.4	3.3
360	4.0	6.7	4.0	7.0	6.0	2.	5.0
$\pm R/2$	6.5	4.9	5.5	5.5	6.5	4.9	3.2
$\bar{x}$	8.4	11.5	5.2	6.9	7.5	5.7	5.8
σ	4.1	3.3	3.5	3.6	3.8	2.9	1.9
RMS	9.3	11.9	6.2	7.8	8.4	6.4	6.0

$\pm R/2$ - STATISTICAL RANGE ÷ 2
$\bar{x}$ ---- ARITHMETIC MEAN
σ ---- STANDARD DEVIATION
RMS -- ROOT MEAN SQUARE

number 1 and near zero in run number 2, which merely indicates that both the POS-406 and the barbed wire present biases that oppose one another. The mean error can be effectively reduced as described in the section on significance of the errors.

The standard deviation, σ, is seen to be 3.7 mils or less for all variable loads, except in the barbed wire cases where it reaches 6.2 and 7.4 mils. If the ramp-open case is excluded along with the barbed wire cases (which is justifiable since they are both abnormal test conditions), the standard deviation reduces to 3.2 mils or less in run number 1, and 2.3 mils or less in run number 2, as seen in table 3.

The root-mean-square (RMS) error peaks at 6.2 mils, excluding the barbed wire and ramp-open cases. This RMS error can be reduced to approach the standard deviation error by removing the mean error as seen in the section on significance of the errors.

The introduction of helmets caused only four of the readings to be different by 1 mil from those of the vehicle-normal column.

The introduction of barbed wire caused 11 of the readings to be different (ranging from -5 to 11 mils) from those of the vehicle-normal column.

The ramp-open case caused 10 of the readings to be different (ranging from -3 to 2 mils) from those of the vehicle-normal column.

The vehicle-back-to-normal case caused eight of the readings to be different (ranging from -1 to 1)* from the initial vehicle-normal column in run number 1, and only three of the readings to be different (ranging from -1 to 1) from the initial vehicle-normal column in run number 2.

Evaluation of the Random Area Test Results. The results of the Random Area Test, table 4, do not include all of the random test runs appearing in table A2 in the appendix because of one disqualifying reason or another (i.e. low-voltage, loose components, etc). The statistical characteristics of table 4 can be summarized briefly as follows:

R/2 ------ 3.2 to 6.5 mils
$\bar{x}$ -------- 5.2 to 11.5 mils
σ -------- 1.9 to 4.1 mils
RMS ------ 6.0 to 11.9 mils

The $\bar{x}$ and RMS values can be minimized through removal of the overall mean value of normal runs as described in the following section.

---

* The measuring accuracy of the POS-Theodolite was limited to a minimum of 1 to 2 mils, which accounts for the difference between the vehicle-normal and the vehicle back-to-normal columns.

Local area magnetometer measurements were made to determine if corrections to the magnetic-to-grid-north declination angle were required (see table 2). Only slight corrections were found (-0.3 mils and 1.1 mils for areas 1 and 2, respectively). These corrections were not included in the results of this report.

Significance of the Errors.

POS-406 Realignment. The POS-406 has an installation bias that would eventually be reduced by rotation of the POS-406 magnetic unit with respect to the vehicle. The amount of rotation would be determined by calculating the mean of the means of a few normal test circle runs. The mean of the means of tables 3 and 4, excluding the barbed wire and ramp open columns, has been determined to be (+)6.5 mils. Rotating the POS-406 has been simulated by translating all of the columns of data in tables 3 and 4 by (-)6.5. The results of this translation appear in tables 5 and 6. Tables 5 and 6 show that the new mean values tend toward zero, and the new RMS values approach the standard deviation of the respective columns, as expected.

Table 6, run 1, Area 1b for the POS-406 - Theodolite case shows the new mean to be 5.4 mils, or more than 2.5 times greater than any of the other new means. This indicated that probably some disqualifying event existed during that particular Area 1b test.

Errors Included in the Standard.

Theodolite as a Standard - Beside the previously discussed circle offset error (see the Variable Load Test section), there also exists a random error caused by a lack of coincidence between the theodolite and the POS-406 readout instants. Wind impulses may have occurred torquing the vehicle during a theodolite measurement, but not during the corresponding POS-406 measurement. Similarly, the vehicle could have been slipping on the fine dust-like soil in sloping areas between the time of the theodolite and the POS-406 readout instants. A vehicle slipping error was experienced in Area 1a, which has a 4- to 5-degree slope. In this case, a repeatibility check was made on the vehicle-heading theodolite measurements before and after a theodolite and tripod dismount-remount cycle. The results showed a change of 3.8 mils over the cycle. Table A3 shows a typical error of 0.686 mils occurring during the theodolite and tripod dismount-remount cycle with the vehicle on level ground; therefore, it is probable that vehicle slippage actually occurred causing a minimum error of 3 mils.

Gyro as a Standard - Using the gyro as a standard during the variable load test would have incurred an unwarranted error from 3.5 to 4.5 mils owing to the gyro drift rate since this test lasted from 1 to 1.5 hours. Superimposed on this error is the gyro readout of ± 0.44 mils. Therefore, the gyro was not used as a standard during the variable load test.

Table 5. Translated Variable Load Test Results
(Translated by -6.5)

INTERVAL DEGREES	POS-406 MINUS THEODOLITE ERROR (MILS)							
	RUN NO. 1					RUN NO. 2		
	VEHICLE NORMAL	VEHICLE W/HEL-METS	VEHICLE W/BARB WIRE	VEHICLE W/RAMP OPEN	VEHICLE BACK TO NORMAL	VEHICLE NORMAL	VEHICLE W/BARB WIRE	VEHICLE BACK TO NORMAL
0	-6.5	-6.5	-11.5	-7.5	-6.5	-0.5	0.5	-0.5
30	-0.3	- .3	3.7	-2.3	- .3	0.4	-1.6	0.4
60	-1.6	-1.6	.4	-4.6	-1.6	1.4	2.4	1.4
90	2.1	2.1	3.1	2.1	3.1	2.0	-1.0	2.0
120	-1.9	- .9	- 7.9	-1.9	- .9	-1.1	-6.1	-2.1
150	-2.9	-2.9	- 0.9	-0.9	-1.9	-5.2	-20.2	-5.2
180	2.1	1.1	2.1	4.1	1.1	-1.4	-15.4	-2.4
210	3.3	2.3	3.3	2.3	2.3	-0.8	-16.8	-0.8
240	1.3	1.3	.3	2.3	1.3	-1.9	0.8	-1.9
270	-2.4	-2.4	- 7.4	-3.4	-1.4	.3	-3.7	0.3
300	-1.4	-2.4	-12.4	-3.4	-1.4	2.5	-2.5	3.5
330	-7.5	-7.5	- 4.5	-7.5	-8.5	-2.1	-9.1	-2.1
360	-2.	-2.0	7.	-4.0	-1.0	-2.1	-11.1	-2.1
±R/2	5.4	4.9	9.7	5.8	5.8	7.7	11.3	4.4
$\bar{x}$	-1.4	-1.5	- 1.9	-1.9	-1.2	- .6	6.4	-0.7
σ	3.2	3.0	6.2	3.7	3.2	2.0	7.4	2.3
RMS	3.4	3.3	6.3	4.1	3.3	2.1	9.6	2.3

±R/2 - STATISTAL RANGE ÷ 2
$\bar{x}$ - ARITHMETIC MEAN
σ - STANDARD DEVIATION
RMS - ROOT MEAN SQUARE

Table 6. Translated Random Area Test Results
(Translated by -6.5)

INTERVAL DEGREES	RUN NO. 1		RUN NO. 2		RUN NO. 3		
	AREA 1b		REF CIR	AREA 2	AREA 1a		AREA 1b
	POS-GYRO	POS-THEO	POS-GYRO	POS-GYRO	POS-GYRO	POS-THEO	POS-GYRO
0	3.5	-0.6	-1.5	0.5	-0.5	-0.5	0.5
30	-5.8	7.2	2.2	5.2	-2.8	-1.3	0.8
60	-2.2	2.3	3.8	2.8	-2.2	-6.4	1.2
90	4.5	8.3	2.5	2.5	-6.5	-1.9	2.5
120	7.2	7.8	1.2	2.2	3.2	-2.6	1.2
150	6.8	6.5	1.8	4.8	4.8	2.7	0.2
180	6.5	7.5	-1.5	4.5	6.5	2.9	0.5
210	3.2	9.1	-2.8	-1.8	6.2	3.4	1.2
240	-3.2	3.6	-1.2	-2.2	.8	0.9	3.2
270	2.5	7.6	-4.5	-3.5	3.5	1.3	0.5
300	2.2	2.7	-6.8	-5.8	0.2	-1.1	3.8
330	1.8	2.8	-7.2	-4.2	0.8	-3.1	3.2
360	-2.5	0.2	-2.5	0.5	-0.5	-4.5	1.5
±R/2	6.5	4.9	5.5	5.5	6.5	4.9	3.2
$\bar{x}$	1.9	5.4	1.3	0.4	1.0	0.8	0.7
σ	4.1	3.3	3.5	3.6	3.8	3.0	1.9
RMS	4.4	5.9	3.6	3.5	3.8	3.0	1.9

±R/2 - STATISTICAL RANGE ÷ 2
$\bar{x}$ --- ARITHMETIC MEAN
σ --- STANDARD DEVIATION
RMS -- ROOT MEAN SQUARE

During the random area test, the various test circles could be completed in 5 minutes (equal to 0.30 mil gyro drift error). The zero setting of the gyro would be set with the zero reading of the POS-406 in this case, which should be acceptable because the zero POS-406 reading has not been changed and because the reading has been correlated with the reference azimuth using the theodolite. This initial zero setting should be accurate to within the Root-Square-Sum of both the POS-406 and the gyro readout errors, which are assumed to be 0.5 mils each, giving the initial gyro-zero setting to within ± 0.7 mils and neglecting the constant phasing errors between each of the two instruments and the vehicle.

Other Indeterminant Errors - The POS-406 and the LNS gyro used during this test were the same components mounted in the vehicle during the previous 6-week FOV tests. During the last test run, the gyro had become noisy and ICU mounting bolts had vibrated loose, causing it to lose calibration. Furthermore, cold solder joints were found on power input leads to the ICU, offering the possibility of high valued random errors with vibration of the vehicle.

CONCLUSIONS

The POS-406, a magnetic type of north reference system, exhibits a heading accuracy that appears to lie within the acceptable range required for the FOV; therefore, future FOV planning and development should include the consideration of both the magnetic and the gyroscope types of north reference before finalization.

APPENDIX. TABULATION OF INITIAL TEST DATA

A tabulation of the initial test data appears in tables A1, A2, and A3.

Table A1 contains the raw test data gathered during the variable load test using the theodolite as the standard and conducted at the reference circle with W. Tower as the distant reference.

Table A2 contains the raw test data gathered during the random area test using the theodolite and/or the directional gyro as the standard during the test. The vehicle was positioned within 0.5 mils of the respective 30° intervals by the driver monitoring the gyro readout directly. The maximum integrated error owing to gyro drift over any random circle was 0.72 mils.

Table A3 contains a verification of the theodolite error caused by vehicle vibration and other causes.

Table A1. Variable Load, Initial Test Data

GYRO INTERVAL DEGREES	RUN NO. 1						RUN NO. 2			
	THEOD-OLITE READINGS (MILS)	POS-406 READINGS (MILS)					THEOD-OLITE READINGS (MILS)	POS-406 READINGS (MILS)		
		VEHICLE NORMAL	VEHICLE W/HEL-METS	VEHICLE W/BARB WIRE	VEHICLE W/RAMP OPEN	VEHICLE BACK TO NORMAL		VEHICLE NORMAL	VEHICLE W/BARB WIRE	VEHICLE BACK TO NORMAL
0	2439.3	0	0	6395	6399	0	2439.4	0006	0007	0006
30	1905.4	0540	0540	0544	0538	0540	1907.2	0539	0537	0539
30	1371.2	1073	1073	1075	1070	1073	1373.2	1074	1075	1074
90	837.9	1610	1610	1611	1610	1611	839.8	1608	1605	1608
120	301.9	2142	2143	2136	2142	2143	304.7	2140	2135	2139
150	6167.9	2675	2675	2677	2677	2676	6172.6	2668	2653	2668
180	5639.9	3208	3207	3208	3210	3207	5639.4	3205	3191	3204
210	5106.1	3743	3742	3743	3742	3742	5106.0	3739	3723	3739
240	4575.1	4272	4272	4271	4273	4272	4572.9	4271	4274	4271
270	4036.4	4807	4807	4802	4806	4808	4039.1	4807	4803	4807
300	3501.4	5343	5342	5332	5341	5343	3502.3	5346	5341	5345
330	2965.3	5873	5873	5876	5873	5872	2968.7	5875	5868	5875
360	2432.8	0011	0011	0020	0009	0012	2437.7	0006	6397	0006

Table A2. Random Area, Initial Test Data

INTERVAL DEGREES	RUN NO. 1				RUN NO. 2							RUN NO. 3				
	AREA 1a		AREA 1b		REF CIR	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	REF CIR	AREA 1a		AREA 1b	AREA 5	AREA 6
	THEO RDG	POS RDG	THEO RDG	POS RDG	POS RDG	POS RDG	POS RDG	POS RDG	POS RDG	POS RDG	POS RDG	THEO RDG	POS RDG	POS RDG	POS RDG	POS RDG
0	3100.2	0006	3096.2	0010	0005	0007	0006	0007	0014	0003	0002	3098.3	0006	0006	0006	0006
30	2566.3	0533	2571.8	0534	0542	0545	0542	0547	0553	0545	0543	2566.5	0537	0539	0545	0543
60	2036.1	1069	2029.9	1071	1077	1076	1075	1082	1092	1082	1075	2027.4	1071	1072	1084	1075
90	1499.3	1609	1495.9	1611	1609	1609	1618	1620	1624	1625	1619	1502.9	1600	1609	1624	1612
120	964.8	2149	959.4	2147	2141	2142	2148	2156	2159	2155	2157	0959.2	2143	2141	2156	2149
150	429.7	2882	425.1	2680	2675	2678	2682	2691	2694	2690	2684	0429.5	2678	2673	2689	2685
180	6295.7	3219	6293.1	3213	3205	3211	3212	3224	3223	3216	3213	6294.7	3213	3206	3217	3214
210	5765.8	3748	5764.7	3743	3737	3738	3748	3754	3754	3747	3743	5762.2	3746	3741	3749	3752
240	5234.2	4276	5232.2	4270	4272	4271	4278	4286	4285	4279	4272	5231.7	4274	4270	4275	4281
270	4698.2	4812	4697.2	4809	4802	4803	4812	4818	4817	4810	4804	4696.1	4810	4807	4806	4807
300	4163.3	5347	4159.3	5342	5333	5334	5343	5347	5348	5340	5336	4163.7	5340	5336	5340	5340
330	3629.3	5877	3626.4	5875	5866	5869	5873	5878	5880	5875	5870	3627.7	5874	5870	5879	5873
360	3098.1	0006	3094.8	0004	0004	0007	0007	0017	0015	0012	0002	3094.3	0006	0005	0009	0011
CMTS	GVS-5 missing and periscope rotated causing out of calibration conditions		(System OK)		(System OK)		Voltage becoming marginal	Low battery voltage			Voltage doubtful	New battery was installed for this period. (System OK)			Noisy Gyro, Loose ICU	

Table A3. Theodolite Verification Test

ITEM	CONDITION SIMULATED (OR REPEATED)	THEODOLITE READING	THEODOLITE CHANGE
1.	Theodolite mounted on vehicle in normal manner tested.	1888.685	
			0.432
2.	Knocking tripod leg with hatch (as inadvertantly occurred during test)	1888.253	
			0.211
3.	Vehicle vibration (simulated by vibrating tripod legs with hands)	1888.042	
			0.686
4.	Removing theodolite and tripod from mounting and reassembling	1888.728	
			0.343
5.	Removing theodolite from tripod	1888.385	

Item 3, (table A3), vibration period, causing a reading change of 0.211 mils, has a possibility of occurring 12 times during the 12 periods of repositioning the vehicle during a typical swing around a test circle giving a possible RSS change of 0.7 mils.

The occurrences of the remaining items were rare enough to cause insignificant error.