3

Center for Night Vision and Electro-Optics

AMSEL-NV-TR-0070

SEARCH AND TARGET ACQUISITION IN CLEAR AIR (SMOKE 5-B FIELD TEST)

by

Donald B. Newman
and
Clarence P. Walters

JANUARY 1989

FORT BELVOIR, VIRGINIA 22060-5677

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AMSEL-NV-TR-0070	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Center for Night Vision and Electro-Optics (CNVEO) 6b. OFFICE SYMBOL (If applicable) AMSEL-RD-NV-V	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Visionics Division Fort Belvoir, VA 22060-5677	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Search and Target Acquisition in Clear Air (Smoke 5-B Field Test) (U)

12. PERSONAL AUTHOR(S)
Donald B. Newman and Clarence P. Walters

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM Oct 83 TO Nov 83	January 1989	130

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Probability of Finding (Pf); Probability of classification (Pc); Probability of recognition (Pr); Probability of Identification (Pi); False Alarm Rate; Search Rate; Search Pattern, 8-12µm Sensors; 3-5um Sensors; Visible Sensors

19. ABSTRCT (Continue on reverse if necessary and identify by block number)

This report describes the results of a field test designed to investigate trained observer personnel target acquisition performance of sensor technologies and search procedures. The report includes the meteorological summaries and the detailed test methodology.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT [x] UNCLASSIFIED/UNLIMITED [x] SAME AS REPORT [ ] DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Donald B. Newman	22b. TELEPHONE (Include Area Code) 703-664-2730 22c. Office Symbol AMSEL-RD-NV-V

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

SUMMARY OF RESULTS

This report describes the analysis and results of the clear air trials conducted during the Smoke 5-B field experiment at Fort Huachuca, AZ, during October and November 1983. The experiment was sponsored and funded by the Project Manger, Smoke and Obscurants (PM-S), Aberdeen Proving Ground, MD, and designed and conducted by the Visionics Division, Center for Night Vision and Electro-Optics (CNVEO), Fort Belvoir, VA. All trials were conducted during daylight hours, generally between 0900 and 1700.

The Probability of Finding (Pf), Classification (Pc), Recognition (Pr), and Identification (Pi) of military vehicle targets situated at ranges between 1,100 and 5,500 meters were determined for each of the sensors available for this test. The results indicate that there are no statistically significant differences in the performance of the thermal sensors with two exceptions: (1) The AN/VSG-2 Tank Thermal Sight had significantly better performance when operated in the "white hot" mode and compared to a similar system operated in the "black hot" mode; and (2) the performance of an AN/TAS-4 with several disabled horizontal scan lines was significantly degraded in comparison to the performance of normally operated AN/TAS-4 sensors.

The Pf performance of the TOW Day Sight approached that of the better thermal sensors and, interestingly, virtually all of the targets that were found while using this device were recognized and/or identified. The performance of the Silicon TV imager was considerably less than that of any other sensor included in these analyses.

The false target response or "false alarm" rate (FAR) for all sensors combined was one false target response for every 18.2 minutes of search, or about one false alarm/sensor/20-minute trial. There were no differences in FARs among the sensors.

There is an indication that a learning effect for Pf existed during the first several trials. This effect was analyzed as a function of the target range. It was found that the observers reached near asymptotic performance within about 10 trials for targets at ranges less than 5,000 meters. The Pf performance for targets beyond 5,000 meters did not asymptote during the test period.

A relationship between high temperature/light cloud cover and Pf for longer range targets was discovered. The Pf was severely degraded for targets beyond 4,000 meters when this condition existed. An examination of calibrated forward looking infrared (FLIR) (target signature) imagery indicated that the thermal clutter can increase dramatically under these conditions. Information provided by the Atmospheric Sciences Laboratory (ASL), consisting of imagery taken with the ASL SMART system, showed that this condition can be very dynamic. That is, cloud movement can cause the thermal terrain environment to change from benign to highly target competitive in a few minutes.

The search performance of all of the sensors was evaluated and analyzed extensively. The principal findings were: (1) the search scan rate was generally much lower while using the visible sensors when compared to the thermal sensors and (2) the search rate, in seconds per field of view (FOV), was less than predicted by the CNVEO Search Model. The mean scan rates for visible sensors were 2.60 and 2.83 degrees per second for the TOW Day Sight and the Silicon TV, respectively. The mean scan rates measured for the thermal sensors were AN/TAS-2, 3.89 degrees/second; AN/TAS-4, 4.35 degrees/second; and AN/VSG-2, 4.01 degrees/second. The search rate, in seconds per FOV for the thermal sensors, was about 1.25 seconds/FOV, which is about 25% less than is currently used in the CNVEO Search Model.

The effect of the search scan rate on the target acquisition performance of thermal sensors was examined by comparing the performance of "slow scan" observers, who searched at a rate slower than one standard deviation from the mean search scan rate, with the remainder of the observers. The data indicated that the Pf (all targets at all ranges) for the slow scan observers was .48 in comparison to a Pf of .55 for the remainder of the observers. It was found, however, that about 15% of the targets were never in the FOV of the sensors operated by the slow scan rate observers.

The analysis of search patterns revealed that most of the observers searched in a routine left-right-left pattern, at about the same rate in each direction. One observer developed a unique and, for him, a highly effective search pattern, searching in the left-to-right direction only. After completing one sweep of the 60 degree field of regard (FOR), he rapidly swung the sensor back to the left side of the search area and then resumed his search. Interviews with the observers revealed that the rationale for this unique search pattern was that the technique enabled him to search all areas of the FOR at a regular time interval.

In addition to providing a statistically reliable data base for several areas related to sensor and search performance, the Smoke 5-B Test demonstrated a highly sophisticated experimental methodology and a reliable method for evaluating and analyzing these data.

TABLE OF CONTENTS

FIGURES

TABLES

SECTION I. INTRODUCTION

This report describes the results of the analyses applied to the Smoke 5-B clear air trials conducted at Fort Huachuca, AZ, during October and November 1983. The experiment was sponsored and funded by the Project Manager, Smoke and Obscurants, and designed and conducted by the Visionics Division of the Center for Night Vision and Electro-Optics (CNVEO), Fort Belvoir, VA. Interpretations of the results for each area of analysis are included. The areas of analysis and the data formats for each area are as follows.

PROBABILITY OF FINDING (Pf), CLASSIFICATION (Pc), RECOGNITION (Pr), AND IDENTIFICATION (Pi)

The data formats include tables and data plots for visible, 3 to 5μm, and 8 to 12μm thermal imagers for each target type at five range bands. The results and a discussion of the results are included. The sensor descriptions are included in Appendix A. The probability data are discussed in Section III. Tables showing the probability data for individual targets are presented as Appendix B, along with sets of plots that compare the performance of individual sensors.

SEARCH SCAN RATE

Tables indicating the search scan rates (degrees/seconds) for each sensor type are presented. Also included are search scan rate tables that show the variance between observers using the thermal sensors. Associated search data, including the relationship between search rate and Pf, are presented and discussed.

SEARCH PATTERNS

Representative search patterns are shown for each sensor type. The search patterns are in graphic form and indicate the position of the sensor within the FOR as a function of time. The search patterns are annotated with target time lines, including target type, position, and range. Included, too, is a discussion of the search pattern data.

TARGET SIGNATURES

Target signatures were measured in three spectral bands: 0.4 to 0.7μm (visible), 0.73 to 0.9μm (silicon), and 8 to 12μm (far infrared). A discussion of the measurement techniques and the results are included as Appendix C.

METHODOLOGY

The test methodology is summarized in Section II. Appendix D includes the detailed methodology, an example of a typical test matrix, target types and quantities, range details, observer training techniques, and descriptions of the performance data acquisition equipment.

METEOROLOGICAL MEASUREMENTS

An extensive meteorological data base was compiled for each trial. These data, and a description of the measurement techniques, are included in Appendix E. Included, too, are daily summary plots of several of the measured meteorological parameters that permit extraction of the meteorological conditions that existed during each trial.

SECTION II. METHODOLOGY AND DATA BASE

METHODOLOGY

The test was conducted on the West Range of Fort Huachuca, AZ. The test area was a fan, 60 degrees in azimuth, that permitted placement of vehicle targets at ranges of 1,100 to 5,500 meters in 200-meter increments. Several positions were selected at most of the ranges. Each position had an adjacent defilade area. As many as 15 target vehicles were positioned in defilade prior to the start of each trial.

A trial consisted of 15 events with three cells in each event. A pseudo random matrix was derived for each trial that permitted from zero to three targets within the search area during each event. The targets were permitted to remain in the search area for about 80 seconds before returning to defilade, at which time the next event would begin. This procedure was used until the trial was completed. A typical trial lasted about 20 minutes. Each of the vehicles was equipped with a transponder that enabled the X/Y position to be determined. This system, the Multi-Target Tracker, was set up so that a signal was received and recorded only when a vehicle was in line of sight to the sensors. The sensors were arranged on an 8 foot high platform at the apex of the test fan. Each of sensors was installed on a shaft encoded tripod that allowed the sensor azimuth to be recorded at a rate of four times/second. Observer responses were recorded via multiple input console. All of the target position, sensor azimuth, and observer responses were input to a Data General computer—the Automatic Field Evaluation Data System (AUTOFEDS), and tagged to IRIG-B time code. The primary observer inputs were: Detection (Finding), Aim, Classification, Recognition, and Identification. Additional inputs were provided for FOV changes (for sensors so equipped) and an Error input that allowed the previous response(s) to be corrected. The "aim" response was input after an observer had found a target and centered the target in the sensor FOV. The sensor azimuth was then compared to the known target azimuth in order to verify the finding of a target (and determine the false target response frequency). The continuous input of sensor azimuth was used to determine the search scan rate and the search pattern for each sensor during each trial.

OBSERVERS

The observers were volunteer military enlisted personnel who were assigned to Fort Huachuca for training in image interpretation or electronics and communications. Twenty-two personnel were in the original group assigned to the observer training program. For various reasons some left the experiment. By the end of the second week of the test, the group achieved its final and stable size of 17 personnel.

Observers always tested in pairs. The first member of the pair operated the sensor (adjusted the focus, set the FOV, adjusted the gain and level, and scanned) and gave target acquisition responses (find, aim, classify, recognize, identify, and start search) while the second member of the pair was responsible for entering the target acquisition responses into a button box. The button box data and pointing angle data from the sensor were entered into the central computer for subsequent data analysis. The two members of each pair were connected by a headset communication link.

OBSERVER TRAINING

The observers were trained in techniques used to find, classify, recognize, and identify military vehicle targets for each of the sensor types. Training included the viewing of video taped sensor imagery and hands-on use of the various sensors. Several trials using the methodology developed for the test were conducted as part of the training phase. The search process was explained to the observers during the training phase. The observers were instructed that they could operate the sensors as they wished, as long as their method was in keeping with the goal of optimizing target acquisition. In short, the observers were told that the search process should be organized, but not **how** it should be organized.

SENSORS

Two AN/TAS-4 TOW Night Sights without modification
One AN/TAS-4 TOW Night Sight with 5-6 scan lines disabled
One AN/VSG-2 Tank Thermal Sight (TTS) "White Hot" mode
One AN/VSG-2 Tank Thermal Sight (TTS) "Black Hot" mode
One AN/TAS-2 Thermal Imager (3 to 5μm)
One Silicon Television (RCA S-11)
One TOW Day Sight Telescope

The thermal imagers are all 8 to 12μm sensors unless otherwise specified.

The AN/TAS-4 with disabled scan lines was included to determine the effect of potential damage to the detector array on sensor performance. One of the AN/VSG-2 TTS sensors was operated exclusively in the "white hot" mode and the other in the "black hot" mode in order to obtain a direct comparison of the two polarity modes.

The minimum resolvable temperature (MRT) of the thermal sensors was measured prior to the field test. The results of these measurements are included in Appendix A.

TRIALS

The data are based upon the results of 117 trials, with each including, on the average, between 26 and 32 individual targets within an approximate 20 minute trial time. All trials were conducted during daylight hours between 0900 and 1700. An additional 28 trials were conducted, but these data were lost due to equipment malfunctions. The data base for the thermal sensors consists of between 90 and 100 trials for each sensor. The Silicon TV data base consists of data from about 60 trials, and the TOW Day Sight data base of data from about 30 trials. Intermittent problems with the shaft encoded tripods resulted in the loss of a substantial amount of the data for the day sensors. Sensor and measurement equipment malfunctions were responsible for the loss of some data for each of the thermal sensors.

DEFINITIONS

Probability of Finding (Pf)

The term Pf is used instead of the more familiar expression, Probability of Detection (Pd). Pd is most commonly associated with method of limits or threshold performance data, as opposed to the dynamic search techniques that were used during the Smoke 5-B trials.

Pf is defined as:

$$\frac{\text{Number of targets found}}{\text{Number of targets available}}$$

This definition does not require the target to have been in the sensor FOV. It simply requires that the target vehicle was in the field of search for some period of time, in this case 60 to 80 seconds. Each target acquisition was produced by comparing the sensor azimuth at the time of the observers' "aim" response with the known azimuth of the target. If the two azimuths matched, the target was "found." If the two did not match, the response was catalogued as a false response, or "false alarm." If the observer was not able to make a higher order response, i.e., classification, recognition or identification, he would resume the search process. Thus, the test design did not require a response beyond the initial target acquisition.

Probability of Classification (Pc)

Classification is defined as the determination that a target is either an armored (tracked) vehicle or a wheeled vehicle.

Probability of Recognition (Pr)

Recognition is defined as the determination of the type of vehicle that has been acquired and classified; for example, that a tracked vehicle is a tank. Note that there are no recognition responses for the wheeled vehicles. Each of the wheeled vehicles was a unique type with no similar competing vehicle.

Conditional Probability of Recognition (CPr)

The CPr is the Pr only for targets that have been found. The CPr provides an indication of the sensor resolution and of the observer's ability to interpret the imagery.

Probability of Identification (Pi)

Identification is defined as the determination of the nomenclature of a vehicle within a given type; for example, that a tank is an M60 tank.

DATA PRESENTATION

For analysis purposes, the target acquisition data were divided into five range bands: "1 to 2km" for targets deployed at 1,100 to 1,900 meters; "2 to 3km" for targets at 2,100 to 2,900 meters; "3 to 4km" for targets 3,100 to 3,900 meters; "4 to 5km" for the targets at 4,100 to 4,900 meters; and ">5km" for targets between 5,100 to 5,500 meters.

TARGET MATRIX

The target matrices that were used during this field test were produced at the conclusion of each test period in an effort to maintain a balance of each target at each range. Overall, this was accomplished satisfactorily, with one important exception: M60 tanks experienced maintenance problems throughout the test. As a result, the number of M60 tank trials for all systems is quite low. The number of target replications for the thermal sensors is generally between 80 and 140 for each vehicle at the three middle range bands and between 40 and 80 at the 1 to 2km band and the 5-5.5km band, with the exception of the M60 tank and, in some cases, the M551 and the M656.

The Silicon TV data base is comprised of between 40 and 100 replicates of most target vehicles at most range bands. The TOW Day Sight data base includes between 20 and 40 target replications for most vehicles at most of the range bands.

CONFIDENCE INTERVALS

The Confidence Intervals (C.I.) at the 90% Confidence Level (C.L.) were determined for probability levels of from 90% to 50% for target replications of from 10 to 150. Confidence intervals at the 90% C.L. are included as Table B-1 of Appendix B.

SECTION III. RESULTS—TARGET PROBABILITIES

AN/TAS-2 THERMAL IMAGER, 3 to 5μm

The Pf, Pc, Pr, and Pi data for military vehicle targets within each range band are presented as Table B-2 of Appendix B. The Pf data indicate that, with the exception of the M561 Gamma Goat, between about 50% and 90% of the targets within 4,000 meters were found. The C.I. for these data are + or – 7% to 9%, dependent upon the target. The Pc and Pr are generally very close to one another, indicating that if the observer was able to classify the target vehicle, he was usually able to recognize it. About 75% of the vehicles that were correctly recognized were correctly identified.

AN/TAS-4 TOW NIGHT SIGHT WITHOUT MODIFICATION

Two AN/TAS-4 TOW Night Sights (S/N 545 and S/N 364-A) without display modification were included in the sensor array. The probability data for these sensors were not combined. The data for the AN/TAS-4 systems are shown as Table B-3 and Table B-4 of Appendix B. There are no statistically significant differences in the probability data for the two AN/TAS-4 sensors without display modification. Although one of the sensors (S/N 545) appears to be slightly better than the other, the slight difference is most likely attributable to the MRT (Figures A-2 and A-3 of Appendix A). The Pf data indicate a C.I. of between 7% and 9% for most targets that were acquired at ranges of 3,900 meters or less. The Pc and Pr are essentially the same at all ranges for the armored vehicles. The Pi are generally about 10% less than Pr (armored vehicles only).

AN/TAS-4 TOW NIGHT SIGHT WITH MISSING DETECTOR LINES

One of the AN/TAS-4 TOW sensors was modified so that several horizontal detector lines in the center of the display could be disabled (S/N FAT-02). This sensor was operated with either five or six missing lines. The probability data indicates that the Pf for this sensor was about 10% to 20% less than the Pf of the unmodified AN/TAS-4 sensors for most of the targets at most ranges. These differences are generally greater than one confidence interval, and are statistically significant. Since the Pc, Pr, and Pi are driven by the Pf, similar differences are seen in these data, too. The MRT data for this sensor are essentially the same as those for the unmodified AN/TAS-4 sensors (Figure A-4 of Appendix A). Interestingly, interviews with the observer personnel indicated that they felt that the missing lines did not affect their performance with this system. The observers stated that they used the portions of the image above and below the missing lines. The probability data for this system are summarized in Table B-5 of Appendix B.

AN/VSG-2 TANK THERMAL SIGHT (TTS) "WHITE HOT" MODE (S/N 013) AND AN/VSG-2 TANK THERMAL SIGHT (TTS) "BLACK HOT" MODE (S/N 003)

The AN/VSG-2 TTS has two display modes: "white hot" and "black hot." Experience has shown that, given a choice, most trained observers will select the "white hot" mode because observers feel that targets are easier to find and interrogate using the white hot imagery. The data indicated that the Pf for the AN/VSG-2 "white hot" was 1 C.I. or greater for most targets at ranges greater than 1,900 meters. Similar differences were seen for Pc, Pr, and Pi for most of the targets and ranges. There was no noticeable difference in the MRT curves for these sensors (Figures A-5 and A-6 of Appendix A). The probability data for the AN/VSG-2 TTS, white hot mode, are presented as Table B-6, and the data for the AN/VSG-2, black hot mode of operation, are summarized as Table B-7 of Appendix B.

SILICON TV

The data base for the Silicon TV was not nearly as large as for the thermal sensors. The number of target replications was between 50 and 100 for most target vehicles at ranges 2,100 to 4,900 meters. The probability data are included as Table B-8 of Appendix B. The Pf was between 50 and 65% for most of the targets at a range of 4,000 meters or less. The C.I. were somewhat larger than most of the systems due to the smaller data base, between 9 and 11%, for most vehicles. The higher order responses indicated that the Pc and Pr were essentially the same. Nearly 90% of the armored vehicles recognized correctly were identified as well.

TOW DAY SIGHT

The system performance data for the Day Sight is summarized as Table B-9 of Appendix B. The data base for the TOW Day Sight was considerably smaller than that of the Silicon TV due to problems with the tripod shaft encoder. On the average, data were obtained for 20 to 40 targets of most types within most of the range bands. The performance data for the Day Sight were somewhat unique in that the Pf, Pc, Pr, and Pi were all within (and mostly well within) 1 C.I. at all ranges out to the maximum 5,500 meters. This result was not entirely unexpected since the Day Sight required little or no image interpretation once a target was found.

COMPARISON OF SENSOR PERFORMANCE

In order to compare the sensors, the probability data for all targets and ranges were combined for each sensor (Table 1).

Table 1. Comparison of Pf, Pc, Pr, and Pi: All Targets and Ranges Combined

SYSTEM	NUMBER	Pf	Pc	Pr	Pi	(NUMBER)	CPr
AN/TAS-2	2,699	.532	.332	.272	.234	(632)	.512
AN/TAS-4 S/N545	2,964	.551	.405	.362	.327	(968)	.657
AN/TAS-4 S/N 364A	2,533	.540	.389	.330	.284	(720)	.610
AN/TAS-4 (Missing Lines)	2,810	.498	.334	.288	.248	(696)	.579
AN/VSG-2 "White Hot"	2,814	.592	.413	.349	.311	(875)	.589
VSG-2 = AN/VSG-2 "Black Hot"	2,514	.514	.334	.269	.231	(581)	.524
TOW Day Sight	859	.508	.466	.455	.447	(384)	.897
Silicon TV	1,835	.396	.278	.240	.216	(396)	.605

The Pf (all targets at all ranges) of the unmodified "white hot" thermal sensors was essentially the same, the mean Pf for all of these sensors combined was .554. The remaining thermal sensors, including the AN/TAS-4 with the missing scan lines and the AN/VSG-2 "black hot," had a combined Pf of .505. The Pf performance differences were particularly evident within the 2 to 5km target ranges. The Pf of the TOW Day Sight was about the same as the modified and "black hot" thermal sensors, while the Pf for the Silicon TV was substantially less than any of the other sensors. The Pc, Pr, and Pi of the AN/TAS-2 were considerably lower than those for the remaining unmodified white hot mode sensors. This was most likely attributable to the MRT (Figure A-1 of Appendix A), which showed a maximum resolution of about 2.75 cy/mrad as compared to a maximum of 4.3 cy/mrad or greater for the other thermal sensors. The Pr and Pi of the black hot mode AN/VSG-2 and the AN/TAS-4 with disabled scan lines were less than those of the similar unmodified white hot systems as well. Similar differences were found in the CPr for these systems. The TOW Day Sight data were somewhat unique because nearly 90% of the targets found were correctly recognized and identified. The CPR of the Silicon TV approached that of the better thermal systems, indicating that observers were able to use this system effectively after targets were found.

TARGET IDENTIFICATION CONFUSION

In order to determine the targets that were confused with one another when identification responses were input, the data was reduced to indicate the Pi responses as a function of target vehicle. These data are presented for each system as Tables B-10 through B-17 of Appendix B and are summarized below in Table 2.

Table 2. Probability of Correct Identification Responses by System and Sensor: All Ranges Combined

	ARMORED VEHICLES				WHEELED VEHICLES			
SYSTEM	M60	M551	M113	M577	M35	M656	M151	GG
AN/TAS-2	.90	.69	.38	.72	.69	.60	.67	.54
AN/TAS-4 S/N 545	.70	.71	.54	.73	.84	.77	.77	.63
AN/TAS-4 S/N 364A	.44	.72	.51	.72	.80	.76	.58	.56
AN/TAS-4 Disabled Scan Lines	.55	.68	.46	.73	.78	.75	.57	.49
AN/VSG-2 White Hot	.64	.65	.57	.70	.75	.76	.68	.62
AN/VSG-2 Black Hot	.71	.57	.47	.62	.62	.54	.75	.45
TOW Day Sight	1.00	.92	.97	.97	.98	.92	1.00	.85
Silicon TV	.93	.79	.64	.73	.80	.78	.82	.54

The data in Table 2 indicate that when an identification response occurred, the response was correct about 70% of the time for most targets. The primary exceptions were the M113 APC and the Gamma Goat. The M113 was confused principally with the M577 APC and the M35 and M656 trucks. The M113 was confused with those targets between 40 and 50% of the time with most of the sensors, or nearly at the level of the Pi. The M60 tank was confused most frequently with the M551 tank, whereas the M551 was confused with the other armored vehicles about equally. The Gamma Goat was most often mistaken for one of the trucks or an APC. Interestingly though, the other vehicles were very infrequently identified as a Gamma Goat; the probability of calling any other vehicle a Gamma Goat was generally less than 5%. In general, when a wrong identification response was made, the response was for a vehicle of the same class; i.e., armored or wheeled. When an exception occurred, the wrong identification was usually for a vehicle of similar size. These data reinforce confidence that observers were well trained and used the sensors effectively.

LEARNING EFFECTS FOR Pf

The data presented as Figure 1 indicate a learning effect for Pf existed for the several initial trials. These data were for all targets and all thermal sensors combined, with each data point comprising five consecutive trials, plotted cumulatively, without regard for the number of targets presented within each range band. The data also indicated that the observer Pf performance for targets beyond 5,000 meters did not asymptote during the trials. The conditional Pr data did not show a similar learning effect, reinforcing that thermal signature interpretation training was adequate. Thus, the learning effects may be influenced by the individual observers' development of a comfortable and effective search strategy.

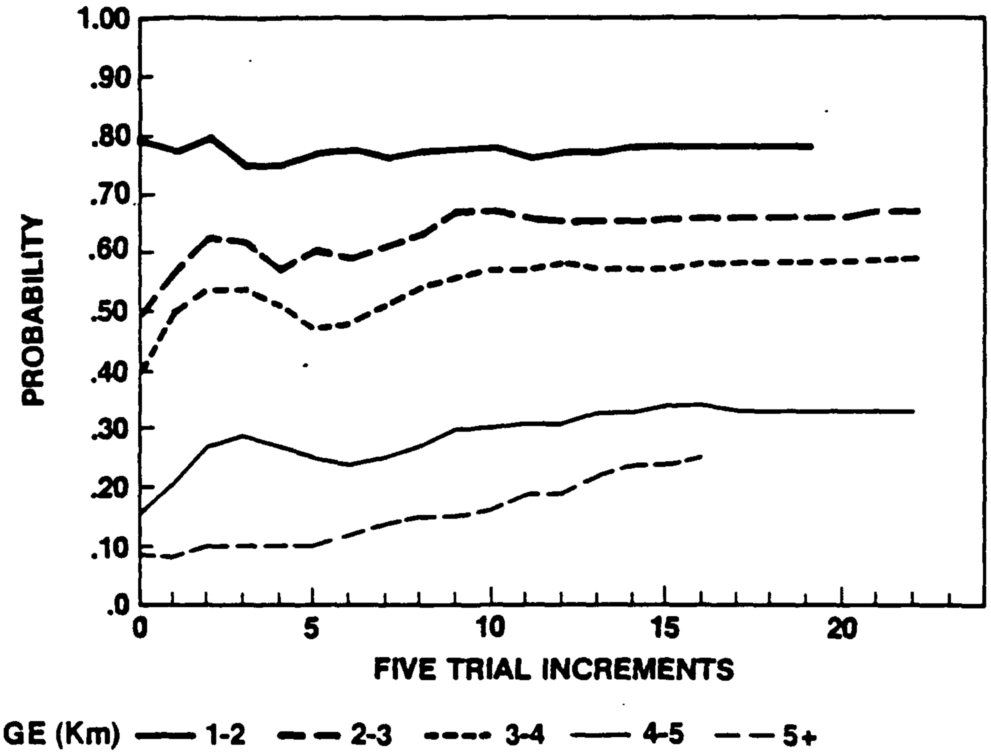


Figure 1. Cumulative Probability of Finding (Pf)

False Alarm Rate (FAR)

A false alarm or false target response is defined as the input of target acquisition response caused by confusing a natural terrain object or clutter with a vehicle target. The FAR, expressed in time of search activity, was determined to be one false alarm per 18.2 minutes of search, or slightly over one false alarm per sensor on the average during each 20-minute trial. The FAR was essentially the same for each thermal sensor.

Environmental Influences on Thermal Sensor Pf

During the evaluation and analysis of the sensor performance data, it was noticed that there were several trials that resulted in very low Pf at ranges beyond 4km for the thermal sensors. Examination of the meteorological data indicated that the only common factors associated with the low Pf trials were relatively high air and ground temperature combined with light or scattered cloud cover. Therefore, the Pf data for trials conducted when the high temperature/light cloud conditions prevailed were compared to the Pf data from all the other trials. The results of these comparisons are shown in Table 3.

Table 3. Comparison of the Pf for Thermal Sensors for Two Environmental Conditions

RANGE (kilometers)	TARGETS	TARGETS FOUND	Pf
Condition I: High Air/Ground Temperature, Light Cloud Cover			
<3	948	546	.576
4 to 5	274	46	.168
>5	265	23	.087
Condition II: All Other Trials			
<3	9,705	6,475	.667
4 to 5	3,741	1,309	.350
>5	1,401	383	.27

The data in Table 3 indicate that there is a severe degradation of the Pf for targets at the longer ranges, particularly under the high temperature/light cloud cover conditions. An examination of video tapes (from the Ford DL-1 Calibrated Infrared Imager used for 8 to 12μm target signature data collection) of several high temperature/light cloud cover trials and of trials conducted during periods of lower temperature/overcast conditions revealed that there was considerably more thermal clutter when the temperature was high and the cloud cover was light than under the other conditions. The thermal clutter under these conditions was probably bare ground, knolls, small prominences, and possibly rock-strewn areas. Many of the clutter "patches" were approximately the same size as the vehicle targets and were therefore competitive to the targets. There was no corresponding increase in the observer FAR for the high temperature/light cloud cover condition. Interestingly, the Pf for targets at ranges less than 4km during these trials was not as severely affected, although less than the mean for the remaining trials. It is possible that the terrain clutter was not as target competitive for the sensor observer at the shorter ranges, or that the resolution of the sensors was sufficient to permit the observer to distinguish between the clutter and the target vehicles because of the greater prominence of unique target cues, such as wheels, tracks, and exhaust systems. Another possibility is that the observers, realizing that the finding of targets at the longer ranges was of a low probability, concentrated their efforts at the shorter ranges. Information provided by the Atmospheric Science Laboratory (ASL) indicated that the thermal clutter could be very dramatic, changing from a rather benign homogeneous thermal environment to one of very target competitive clutter in as little as 5 minutes. A comparison of color photographs with photographs of thermal imagery produced at the same time by the ASL SMART system indicated that the thermal clutter may be manifested by the movement of clouds over the test range. The clouds could shield areas and, within a few minutes, move and permit a high thermal radiance condition that resulted in the high thermal terrain clutter.

SECTION IV. SEARCH SCAN RATE

DEFINITION

The search scan rate is defined as the rate, in degrees/seconds, that an observer slews or scans a sensor while performing the target acquisition task. The search scan rates derived were based upon a pair of subjective search scan rate thresholds. Scan rates of less than 1.0 degrees/second were the lower threshold, and scan rates of greater than 10.0 degrees/second were the upper threshold. Sensor movement of less than the lower threshold could correspond to target interrogation, sensor adjustment or idle time. Sensor movements faster than the upper threshold were probably too fast to permit target acquisition. Sensor azimuths, the basis for computation of search scan rate, were determined at 1-second intervals. The search scan rate data from each trial for each sensor were sorted into 0.5 degree/second bins. Data within the subjective threshold limits were reduced to determine the mean search rate for each sensor during each trial. It should be noted that, with few exceptions, search scan rates greater than the upper threshold occurred very infrequently. The principal exception being the data from one observer who used a search procedure that was unique compared to the other observers.

RESULTS

Search Rates For Thermal And Visible Sensors

Table 4 describes the search rate data for each type of sensor, with the search rate expressed as degrees/second and as seconds/sensor FOV for the fixed FOV sensors, and for the sensor that was used predominantly in one FOV.

Table 4. Search Rates for Thermal and Visible Sensors

	HORIZONTAL FOV	NUMBER	degrees/sec	sec/FOV
THERMAL SENSOR:				
AN/TAS-2	5.0	90	3.89	1.28
AN/TAS-4	2.26 or 6.8	298	4.35	*
AN/VSG-2	5.0 or 15.0	190	4.01	1.25**
VISIBLE SENSOR:				
Silicon TV	5.0	67	2.83	1.77
TOW Day Sight	5.5	31	2.60	2.20

* The observers reported that both the narrow FOV and the wide FOV were used for search.

** Most observers reported that they searched exclusively with the narrow FOV. The search rate (seconds/FOV) assumes narrow FOV search.

The search rate data generated several interesting implications. First, the search rates in seconds/ FOV for the thermal sensors (permitting the assumption that search was conducted in the narrow FOV with the AN/VSG-2), were quite close. These data indicated that the search time per horizontal FOV was about 25% less than is currently used in the CNVEO Search Model. Secondly, the search rates (degrees/ seconds) seemed to imply that the information content of the image was an important contributor to the overall search rate. This implication is supported by the following observation: The test range contained significant natural terrain clutter in the form of trees, shrubs, and other foliage. Note that the search rates were considerably slower for the visible spectrum sensors than for the thermal sensors. The observers using the visible sensors had to contend with the natural clutter while searching for the vehicle targets, thus requiring a slower search rate in order to process the information content.

Search Rate and Pf

The probability of finding a target could be related to the rate at which an observer searched with a sensor. To investigate this possibility, those observers that searched at a rate of one or more standard deviations less than the mean search rate of a system were extracted from the total search rate data base. Table 5 presents the search rates and the Pf and Pr for the two resulting groups. Note that the Pf difference is .07 while the Pr difference is only .03.

Table 5. Search Rate and Pf and Pr for Two Groups of Observers

OBSERVER TYPE	SEARCH RATE deg/sec	TARGETS PRESENTED	TARGETS FOUND	Pf	TARGETS RECOG.	CPr
Slow	2.78	2,371	1,147	.48	599	.61
Other	4.42	13,963	7,635	.55	4,434	.58

The performance data for the slow scan observers was further analyzed and compared to the other observers in order to gain some insight into **why** the slow scan rate affected the Pf. The data in Table 6 lists the Pf, Pr, and CPr for the two observer groups, and the CPf for the slow observers.

Table 6. Comparison of Observer Groups by Target Range: Thermal Sensors

Observer Type I: Slow Scan Rate Observers

RANGE (kilometers)	TARGETS PRESENTED	TARGETS FOUND	Pf	CPf*	TARGETS RECOG.	Pr	CPr
1-2	336	217	.646	(.759)	165	.491	.760
2-3	609	355	.583	(.685)	241	.396	.679
3-4	603	301	.499	(.587)	187	.310	.621
4-5	525	178	.339	(.399)	74	.141	.416
> 5	298	96	.322	(.379)	32	.107	.333

Observer Type II: All Other Observers

RANGE (kilometers)	TARGETS PRESENTED	TARGETS FOUND	Pf	TARGETS RECOG.	Pr	CPr
1-2	1,995	1,598	.801	1,202	.602	.752
2-3	3,510	2,400	.683	1,550	.442	.646
3-4	3,600	2,150	.597	1,146	.318	.533
4-5	3,490	1,177	.337	435	.125	.370
> 5	1,368	310	.226	101	.074	.326

$$* \text{ CPf} = \frac{.85 \text{ of Targets Presented}}{\text{Targets Found}}$$

Table 6 data shows that the slow scan observers found a smaller percentage of targets at ranges within 4,000 meters. The Pf was essentially the same as for the other observers at the longer ranges. The Pr, except for the shortest range targets, was about the same for both groups, and the CPr were very similar at all ranges. These data indicated that the two observer groups were equally skilled at recognizing targets. A large sample of search patterns, annotated with target time lines and observer responses, were analyzed. The search pattern plots for the slow scan rate observers were compared to the patterns for other observers. The targets that were in the FOV of a sensor at least once were determined for each group of search patterns. This analysis revealed that 15.1% of the targets in the slow scan group search pattern targets were never in the FOV of a sensor. (See Figure 2 for an example.) A similar determination using the other group search patterns showed that less than 2% of the targets were never in the FOV of the sensors. If one considers only the targets that were in the FOV of a sensor during the slow scan group trials, then a Conditional Probability of Finding (CPf) could be derived, as shown in Table 6. For example, the slow scan group of observers found 217 of the 336 targets present at ranges between 1 to 2km, for a Pf of .646. If only the 85% of the targets that were in the field of a sensor were considered, then the CPf would be .759 compared to the Pf of .801 for the other observer group. The CPf of the slow scan observers for targets between 2 and 3km and 3 and 4km was essentially the same as the Pf for the other observer group. The Pf for the two groups was similar for targets at the longer ranges and, as a result, the CPf for the slow group was somewhat greater than the Pf for the other observer group. This may be because the slower scan rate permitted the observer to process less information per unit time, which could be an advantage for targets that are more difficult to find. The CPf for all targets at all ranges for the slow group would be .53 compared to the Pf of .55 for the other observers. Thus, it is apparent that the slower search scan rate adopted by some of the observers could impose a penalty on sensor performance in the environment used for this experiment, since the methodology permitted each target to be within the FOR for only about 60 to 80 seconds before returning to defilade.

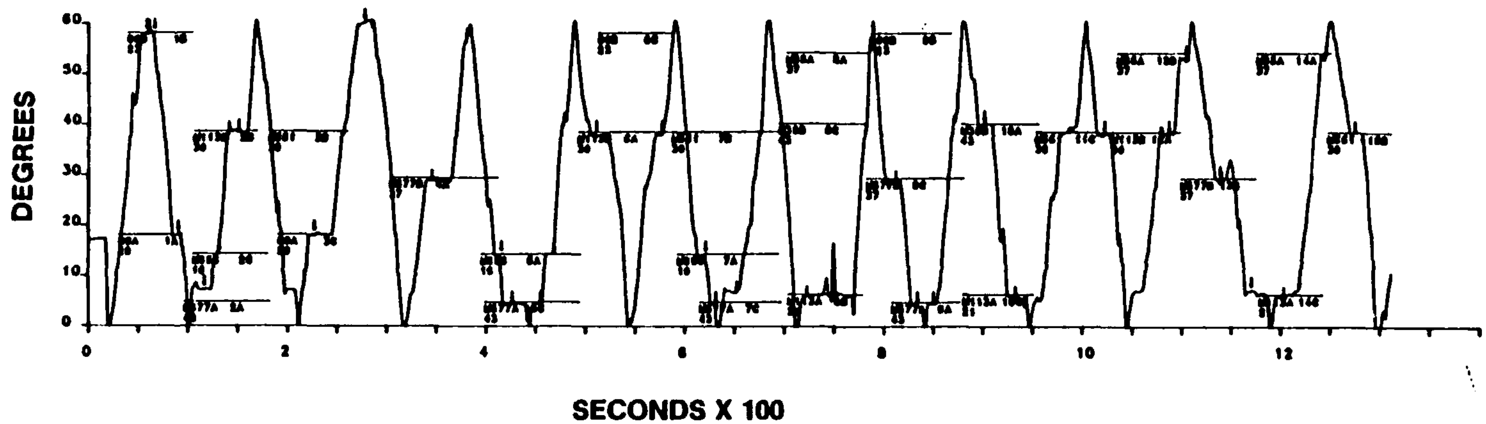


Figure 2. Trial 166 AN/TAS-2 Observer 20 P Finding
0.77 Search Rate 1.99 degrees/sec

SECTION V. SEARCH PATTERNS

DEFINITION

The search patterns are computer output X/Y plots of sensor azimuth vs. time. The plots were derived from the sensor azimuth data at 1-second intervals.

RESULTS

Over the course of the trials, most observers developed a systematic approach to exploration of the FOR. The search patterns presented as Figures 2 through 6 were selected as typical to illustrate the variations in the approach to effective search used by the observers during the experiment. Note that 0 degrees azimuth defined the left side of the search field, and the target information (including target type, range, azimuthal location, and duration of exposure) was annotated on each search pattern. Figure 2 is the search pattern of an observer using the AN/TAS-2. Note that some targets were never within the sensor FOV. This pattern is typical of the slow scan rate patterns used to establish the relationship between search rate and Pf. Figure 3 is the search pattern of the same observer using an AN/TAS-4, a dual FOV thermal sensor. The difference in search activity was possibly related to FOV differences; i.e., the observer searched using both wide and narrow FOV with the AN/TAS-4. The search rate (3.15 degrees/second) was more than one standard deviation from the mean for the AN/TAS-4 and, as a result, included in the slow search group. Note, however, that all of the target vehicles were in the sensor FOV, although several appeared only once and no target was within the sensor FOV more than twice.

Figure 4 depicts the search pattern of an observer who developed a unique and highly effective search strategy. This observer searched in one direction (left to right) then, very quickly, returned the sensor from right to left before resuming his search of the FOR. Consequently, the actual search activity was conducted while moving the sensor only from left to right. According to the observer, this procedure was used to insure that the time elapsing between successive interrogations of the same area within the FOR was the same as for any area within the FOR. Note the nearly vertical 60 to 0 degree sensor excursions depicted in the search pattern. Also interesting is that each target was within the FOV of the sensor several times during each target presentation, in comparison to other representative search patterns (Figures 2 and 6) where some targets were never within the sensor FOV. Most observers, however, adopted a routine left-right-left search pattern. Figure 5 is a typical example of the routine search procedure.

Finally, another search style characterized by incomplete sweeps of the FOR is shown as Figure 6. This search pattern was generated by an observer using the AN/VSG-2 dual FOV sensor.

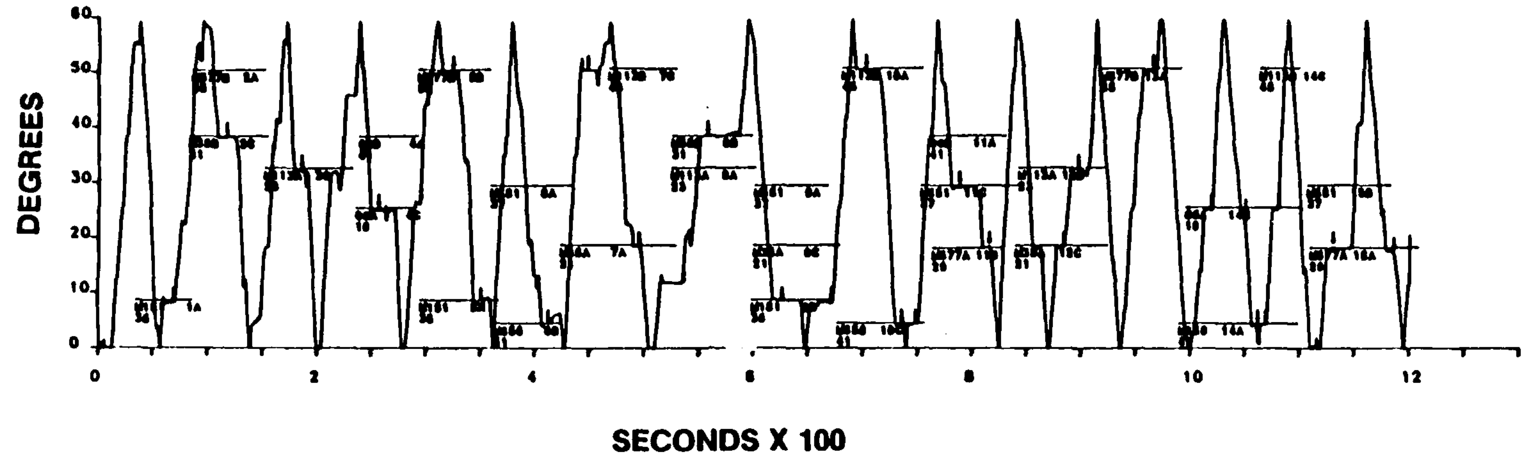


Figure 3. Trial 181 AN/TAS-4 Observer 20 P Finding
0.77 Search Rate 3.15 degrees/sec

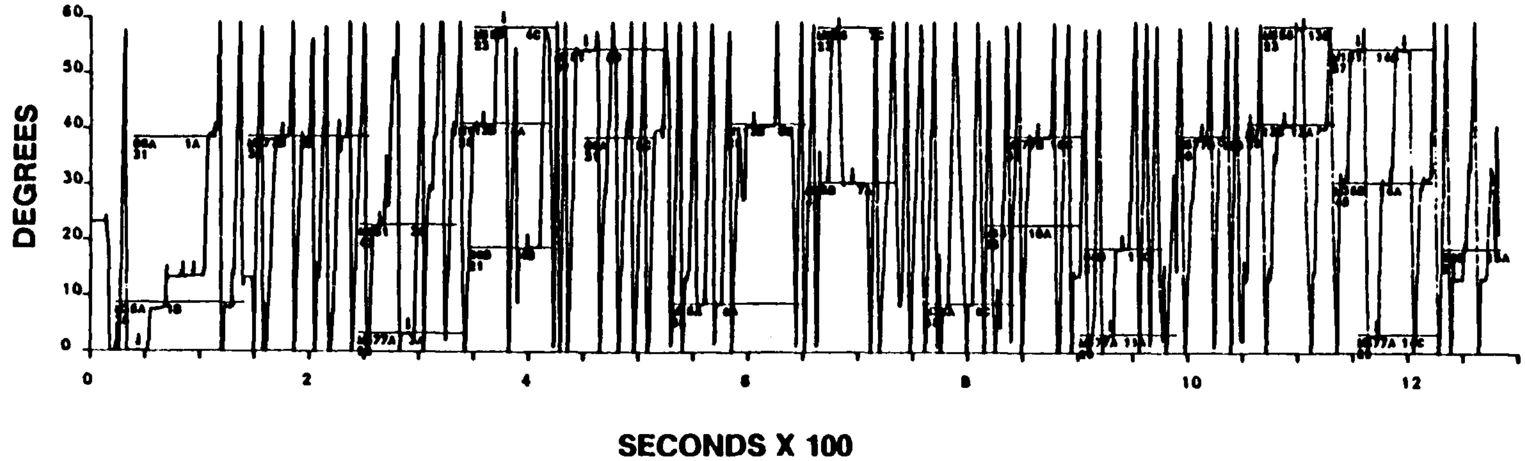


Figure 4. Trial 174 AN/TAS-4 Observer 13 P Finding
0.92 Search Rate 5.88 degrees/sec

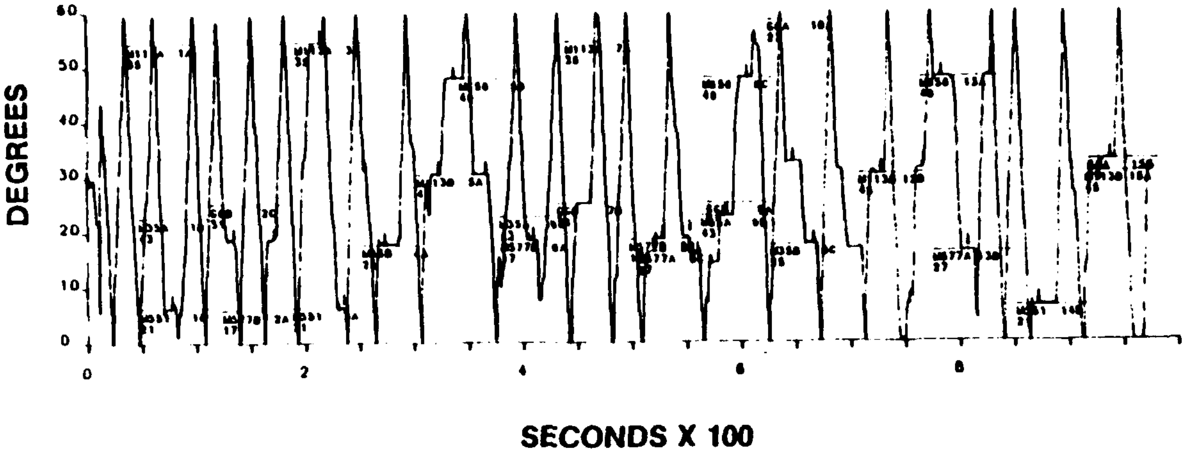


Figure 5. Trial 202 AN/TAS-4 Observer 23 P Finding 0.67 Search Rate 4.96 degrees/sec

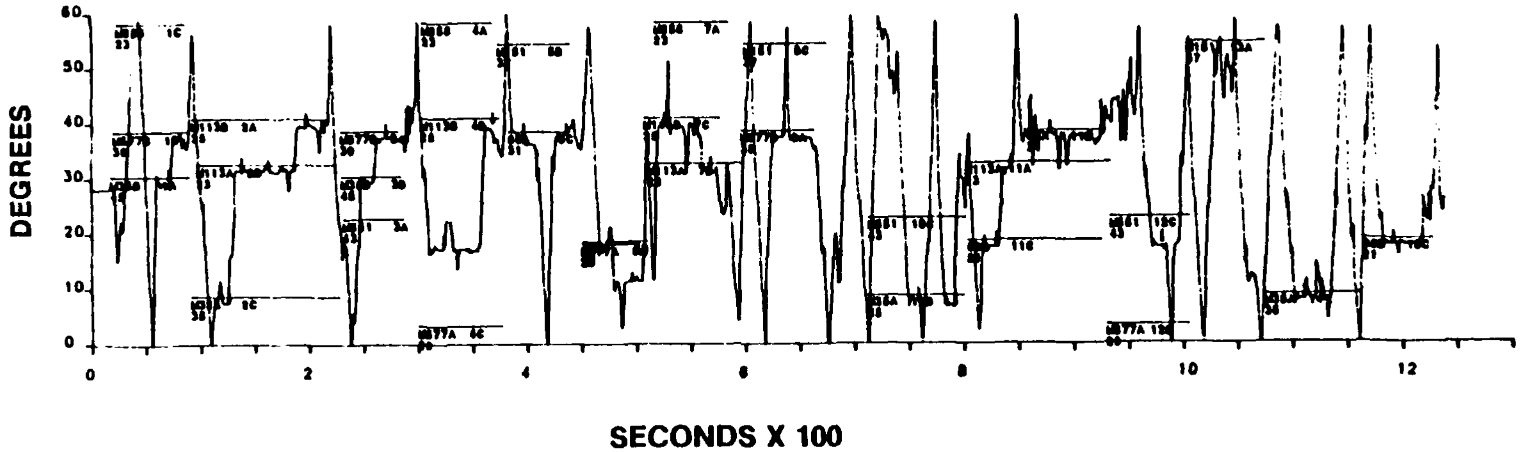


Figure 6. Trial 177 AN/VSG-2 (White Hot) Observer 26 P Finding 0.73 Search Rate 4.30 degrees/sec

SECTION VI. LESSONS LEARNED

Overall, the Smoke 5-B field experiment was very successful. However, deficiencies became obvious; some during the experiment and some after it was completed and data evaluation and analysis were underway.

The principal deficiency was the technique used to input observer response information to the Automatic Field Evaluation Data System (AUTOFEDS) computer. The technique, which required the observer to report responses to a data input push button console operator via a closed circuit microphone/headphone system, was known to have a time delay for data input associated with it. More importantly, though, was the dependence upon the clarity of the voice communication and the accuracy of the data input console operator.

The inability to video record the imagery of the thermal sensor imagery while the operator searched was another deficiency. As a result, it was not possible to subjectively determine what target signature information was used to find and recognize or identify vehicles, and, at least equally important, why targets in a sensor FOV were not found.

A third deficiency was the inability to output collated data during the experiment. In fact, much of the software used to reduce the data to a usable format was written after the experiment ended. Only a rudimentary capability existed during the experiment, and most of this software was developed on site.

SECTION VII. CONCLUSIONS

1. There are no statistically significant differences in the overall performance of the unmodified white hot image thermal sensors for the conditions tested.

2. Modification of an AN/TAS-4 TOW Night Sight by disabling five or six (horizontal) scan lines in the center of the display results in a statistically significant degradation of performance in comparison to similar, but unmodified, sensors.

3. The performance of AN/VSG-2 Thermal Tank Sight operated in the white hot mode is statistically and significantly superior to the performance of this system operated in the black hot image mode.

4. The TOW Day Sight performance was nearly equal to the overall performance of the thermal systems under daylight conditions, while the measured performance of the Silicon TV was significantly less than the performance of any of the other systems.

5. The mean search rates for visible sensors (TOW Day Sight and Silicon TV) were slower than for the thermal sensors. The reasons for this seem apparent; however, the relationship of search rate and the ability to find targets is not fully understood.

6. Most of the observers developed a routine left-right-left search pattern regardless of the sensor they were using. A few observers exhibited at least an occasional erratic search pattern where they would change the direction of search prior to completing a full scan of the FOR. One observer developed a unique and very effective search pattern. The rationale for this unique search procedure, as explained to the analysts was very sound. The effectiveness of the pattern and the rationale should be further expiored and, if the results indicate, should be of significant value in the training of sensor user personnel.

7. There appears to be a relationship between search scan rate and the probability of finding vehicle targets when using thermal sensors. The analysis shows that the performance differences are related to targets never in the FOV of the sensor when the observer searches at a rate substantially slower than the mean. In addition, the analysis revealed that there were no obvious differences in the target interrogation skills when comparing the slow search rate observers with the remainder of the group.

APPENDIX A
SENSOR DESCRIPTIONS

Five sensor types were used during the Smoke 5-B field test. Three of these sensors are presently in the US Army inventory—the AN/TAS-4 TOW Night Sight, the AN/VSG-2 TTS, and the AN/TAS-4 TOW Day Sight. The AN/TAS-2's 3 to 5μm Thermal Imager was type classified and a small quantity was manufactured. The Silicon TV was made up of commercially available components. The Minimum Resolvable Temperature (MRT) data for the thermal imagers, as measured by CNVEO, are included as Figures A-1 through A-6.

NIGHT VISION SIGHT, INFRARED, AN/TAS-2

Purpose:	The AN/TAS-2 is a limited production 3 to 5μm imager which was manufactured by Hughes Aircraft Company in 1971. The sensor, though type classified for limited production, was never placed in the US Army inventory.
Field of View:	2 x 5 degrees
Magnification:	6x
Power Requirements:	24 volts DC

NIGHT VISION SIGHT, INFRARED, AN/TAS-4 (TOW NIGHT SIGHT)

Purpose:	The AN/TAS-2 is designed to mechanically interface with the TOW weapon system and provide a day/night capability to detect, recognize, and identify armored vehicles. The AN/TAS-4 has the capability for both ground and vehicle (M151 jeep, M113 APC, and ITV/FISTV) mounted modes.
Issue Status:	*Initially fielded January 1980*
Weight:	18.7 pounds with one battery and one coolant cartridge
Size:	11.55 inches wide x 19.6 inches long x 8.1 inches high
Range:	3,000 meters
Magnification:	Narrow FOV 12x; Wide FOV 4x
Field of View:	Narrow FOV 1.13 x 2.26 degrees; Wide FOV 3.40 x 6.80 degrees
Power Required:	6.5 watts; 4.8 volts DC
Developer:	CNVEO, Fort Belvoir, VA

TANK, THERMAL SIGHT, AN/VSG-2

Purpose:	The Tank Thermal Sight (TTS) is a daylight sight (1x and 8x) combined with a thermal sight. The TTS and a laser rangefinder are coupled to an on-board ballistic computer to form a highly sophisticated fire control system. The TTS is used exclusively with the M60A3 tank.
Technology:	First Generation Thermal Imaging
Issue Status:	Initially fielded January 1981; continuing on a 1:1 basis with the M60A3 tank
Weight:	Approximately 90 pounds
Magnification:	2.67x and 8x (thermal)
Field of View:	Narrow FOV 2.58 x 5 degrees; Wide FOV 7.74 x 15 degrees
Power Required:	18 to 30 volts DC from vehicle power source
Developer:	CNVEO, Fort Belvoir, VA

DAY SIGHT, TOW WEAPON SYSTEM

Purpose:	The TOW Day Sight Telescope was furnished to provide a daylight target acquisition capability for the TOW Weapon System during clear weather. The Day Sights are boresighted to the TOW Night Sight and TOW Missile Launcher and have the same deployment capability.
Weight:	32 pounds
Size:	13 inches wide x 22 inches long x 14 inches high
Range:	3,000 meters
Magnification:	13x
Field of View:	5.5 degrees

SILICON TELEVISION

The Silicon TV sensor was assembled from the following components:

- RCA Video Camera, Model S-11, 120 volts, 60Hz AC
- Nikon 50 to 300mm f=4.5, 35mm camera lens with "C" mount adapter and 0.6 to1.1μm band pass filter
- Panasonic 9-inch (diagonal) black and white video monitor

The lens was set for a focal length of 230mm, providing a horizontal FOV of about 5 degrees with a magnification of about 7.5x. The lens was stopped down to f=22; however, neutral density filters were required most of the time, resulting in an effective aperture of about f=45.

FIGURE A-1

MINIMUM RESOLVABLE TEMPERATURE (MRT)
AN/TAS-2 NOD-LR SN/205

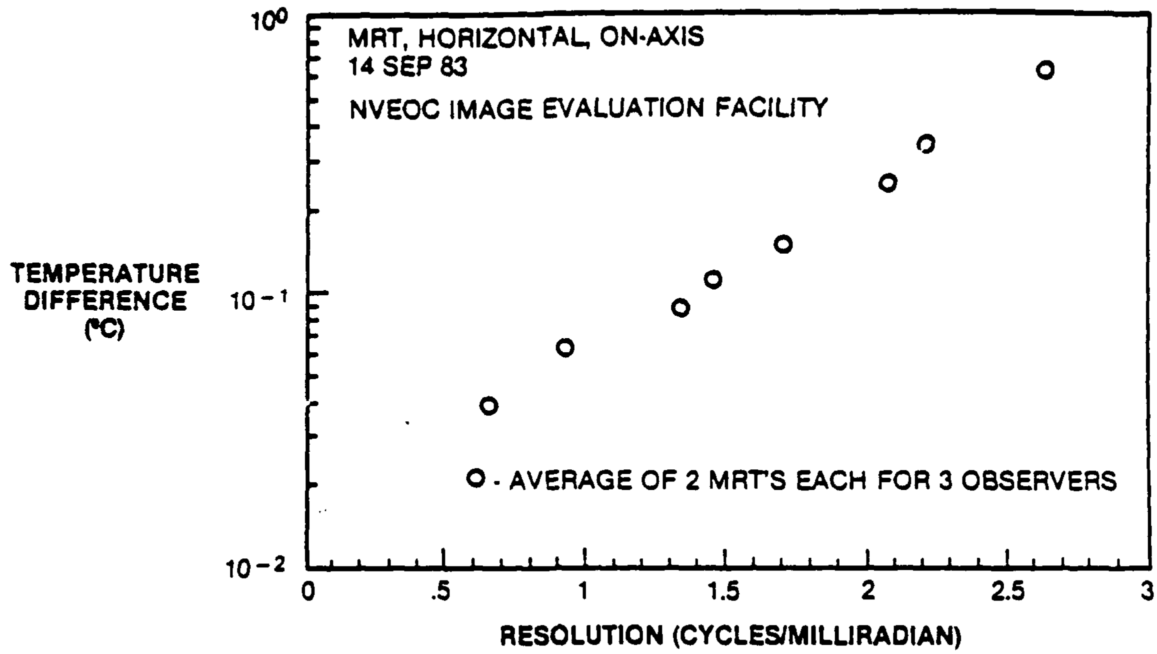


FIGURE A-2

MINIMUM RESOLVABLE TEMPERATURE (MRT)
AN/TAS-4 NIGHT VISION SIGHT, INFRARED (TOWNIGHT SIGHT) S/N545

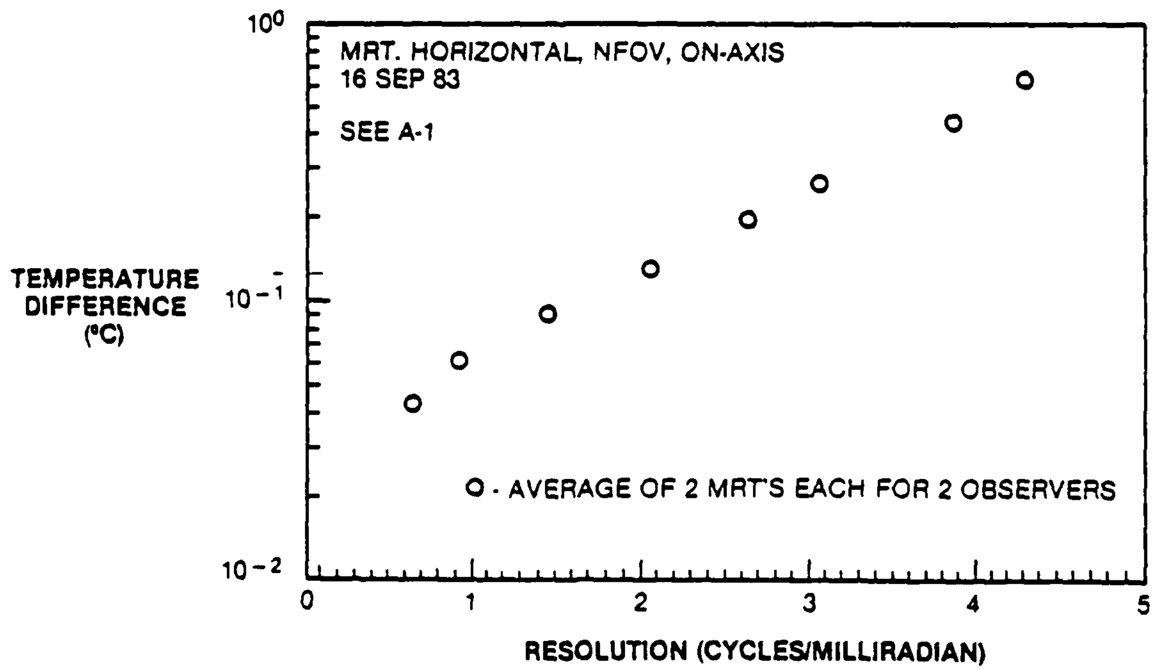


FIGURE A-3

MINIMUM RESOLVABLE TEMPERATURE (MRT) AN/TAS-4 NIGHT VISION SIGHT, INFRARED (TOW NIGHT SIGHT) S/N 364-A

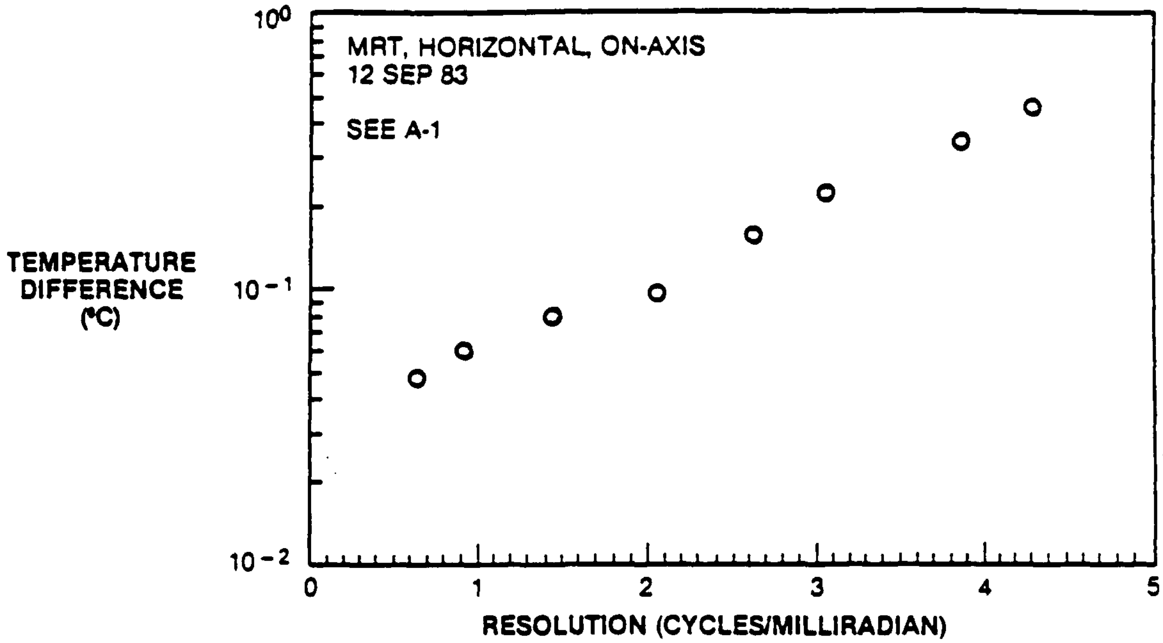


FIGURE A-4

MINIMUM RESOLVABLE TEMPERATURE (MRT) AN/TAS-4 NIGHT VISION SIGHT, INFRARED (TOW NIGHT SIGHT) S/N FAT-02

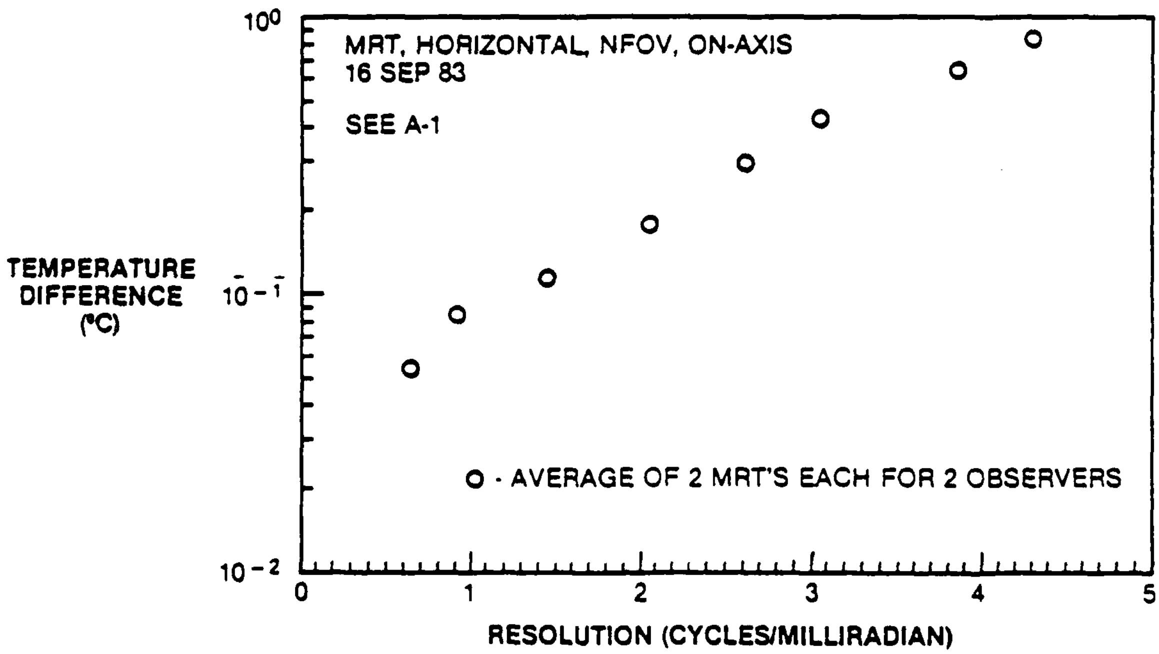


FIGURE A-5

MINIMUM RESOLVABLE TEMPERATURE AN/VSG-2 THERMAL TANK SIGHT (TTS) S/N 013

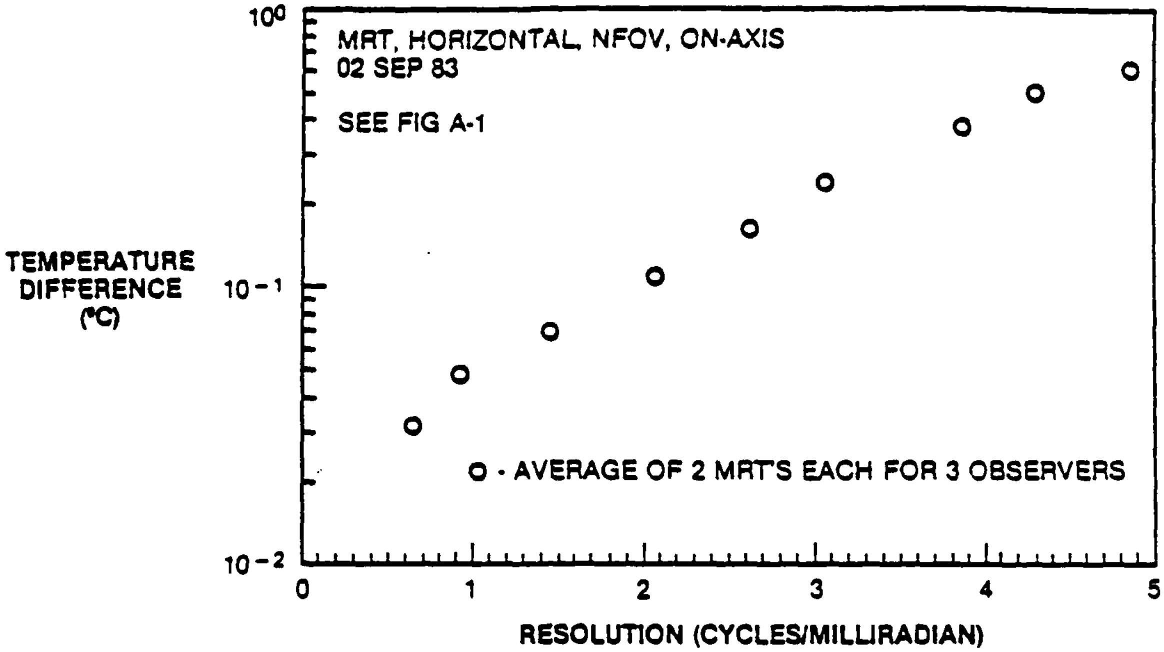
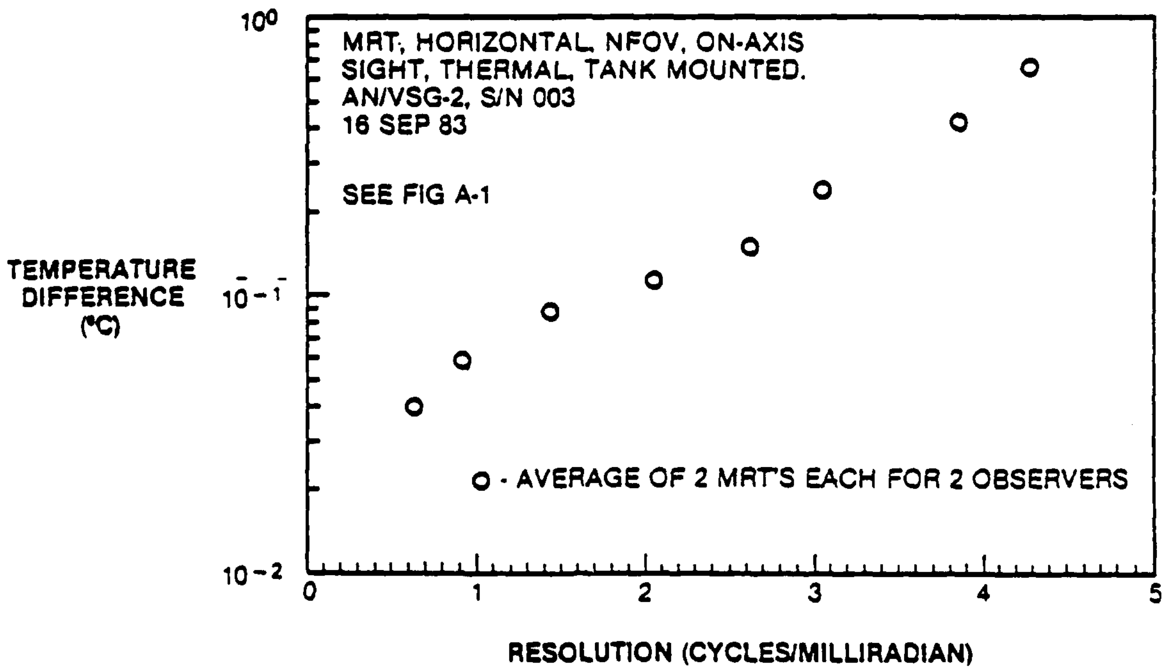


FIGURE A-6

MINIMUM RESOLUABLE TEMPERATURE AN/VSG-2 THERMAL TANK SIGHT (TTS) S/N 003



APPENDIX B
DATA TABLES AND GRAPHS

FIGURES **Page**

TABLES

TABLE B-1

CONFIDENCE INTERVALS AT THE 90% CONFIDENCE LEVEL
FOR PROBABILITY LEVELS OF 90%, 80%, 70%, 60%, 50%

TARGET REPLICATIONS	CONFIDENCE INTERVALS (+ OR -) 90%	80%	70%	60%	50%
10	15.6	20.7	23.8	25.4	25.9
20	11.0	14.7	16.8	18.0	18.3
30	9.0	12.0	13.7	14.7	15.0
40	7.8	10.4	11.9	12.7	13.0
50	7.0	9.3	10.6	11.4	11.6
60	6.4	8.5	9.7	10.4	10.6
70	5.9	7.8	9.0	9.6	9.8
80	5.5	7.3	8.4	9.0	9.2
90	5.2	6.9	7.9	8.5	8.6
100	4.9	6.6	7.5	8.0	8.2
110	4.7	6.3	7.2	7.7	7.8
120	4.5	6.0	6.9	7.3	7.5
130	4.3	5.8	6.6	7.0	7.2
140	4.2	5.5	6.4	6.8	6.9
150	4.0	5.4	6.1	6.6	6.7

TABLE B-2

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: AN/TAS-2 3 TO 5 um THERMAL IMAGER (SERIAL # 205)

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	5	100.0	100.0	100.0	100.0
2-3 KM	12	66.7	58.3	58.3	41.7
3-4 KM	18	55.6	38.9	38.9	33.3
4-5 KM	9	33.3	33.3	33.3	33.3
>5 KM	NO TARGETS AT THIS RANGE				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	14	85.7	85.7	85.7	64.3
2-3 KM	85	60.0	49.4	43.5	34.1
3-4 KM	84	51.2	27.4	17.9	15.5
4-5 KM	83	18.1	6.0	3.6	1.2
>5 KM	19	15.8	5.3	5.3	5.3

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	71	73.3	54.9	49.3	31.0
2-3 KM	118	66.9	40.7	36.4	22.0
3-4 KM	122	69.7	29.5	23.8	11.5
4-5 KM	130	32.3	7.7	6.9	1.5
>5 KM	56	21.4	3.6	3.6	0.0

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	67	61.2	59.7	59.7	53.7
2-3 KM	116	67.2	56.9	53.4	44.8
3-4 KM	106	64.2	44.3	40.6	27.4
4-5 KM	115	55.7	31.3	20.0	10.4
>5 KM	80	31.3	6.3	6.3	5.0

TABLE B-2 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: AN/TAS-2 3 TO 5 um THERMAL IMAGER (SERIAL # 205)

TARGET: M-651 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	65	60.0	49.2	40.0
2-3 KM	103	44.7	25.2	18.4
3-4 KM	100	25.0	8.0	5.0
4-5 KM	108	15.7	3.7	0.0
>5 KM	55	3.6	0.0	0.0

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	38	89.5	76.3	73.7
2-3 KM	67	80.6	59.7	49.3
3-4 KM	68	80.9	55.9	42.6
4-5 KM	71	46.5	23.9	9.9
>5 KM	23	52.2	21.7	4.3

TARGET: M-35A2 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	71	87.3	73.2	59.2
2-3 KM	99	80.8	62.6	51.5
3-4 KM	108	69.4	46.3	37.0
4-5 KM	105	55.2	29.5	21.9
>5 KM	55	38.2	18.2	12.7

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	50	72.0	34.0	32.0
2-3 KM	73	68.5	34.2	24.7
3-4 KM	73	47.9	28.8	23.3
4-5 KM	51	9.8	2.0	2.0
>5 KM	9	11.1	0.0	0.0

TABLE B-3

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: AN/TAS-4 TOW NIGHT SIGHT (SERIAL # 0545)

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	5	60.0	40.0	40.0	40.0
2-3 KM	24	83.3	70.8	66.7	54.2
3-4 KM	22	45.5	54.5	45.5	36.4
4-5 KM	11	63.6	36.4	27.3	0.0
> 5 KM	NO TARGETS AT THIS RANGE				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	14	92.9	85.7	85.7	78.6
2-3 KM	89	56.2	46.1	39.3	36.0
3-4 KM	89	56.2	39.3	38.2	31.5
4-5 KM	80	23.7	11.2	10.0	7.5
>5 KM	19	15.8	0.0	0.0	0.0

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	80	87.5	61.2	55.0	43.8
2-3 KM	125	68.8	43.2	42.4	28.8
3-4 KM	142	59.2	36.6	35.2	28.2
4-5 KM	147	27.2	17.7	15.6	9.5
>5 KM	55	16.4	7.3	7.3	3.6

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	67	79.1	77.6	77.6	74.6
2-3 KM	127	75.6	62.2	61.4	51.2
3-4 KM	119	68.9	52.9	51.3	38.7
4-5 KM	135	46.7	29.6	27.4	18.5
>5 KM	82	24.4	12.2	11.0	8.5

TABLE B-3 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: AN/TAS-4 TOW NIGHT SIGHT (SERIAL # 0545)

TARGET: M-561 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	86	67.4	53.5	52.3
2-3 KM	107	48.6	28.0	24.3
3-4 KM	118	42.4	22.0	11.0
4-5 KM	110	18.2	8.2	1.8
>5 KM	57	10.5	1.8	1.8

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	38	81.6	63.2	57.9
2-3 KM	77	74.0	67.5	61.0
3-4 KM	73	97.3	89.0	69.9
4-5 KM	79	59.5	40.5	29.1
>5 KM	23	21.7	17.4	13.0

TARGET: M-35 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	85	91.8	85.9	80.0
2-3 KM	114	71.9	60.5	54.4
3-4 KM	124	66.9	57.3	50.8
4-5 KM	104	45.2	33.7	26.9
>5 KM	61	27.9	19.7	16.4

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	53	75.5	43.4	39.6
2-3 KM	85	77.6	57.6	50.6
3-4 KM	75	50.7	28.0	21.3
4-5 KM	54	11.1	9.3	7.4
>5 KM	9	0.0	0.0	0.0

TABLE B-4

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: AN/TAS-4 TOW NIGHT SIGHT (SERIAL # 364A)

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	5	80.0	60.0	60.0	40.0
2-3 KM	15	73.3	66.7	60.0	40.0
3-4 KM	20	35.0	30.0	25.0	0.0
4-5 KM	3	66.7	0.0	0.0	0.0
>5 KM	-------NO TARGETS AT THIS RANGE--------------------				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	12	75.0	75.0	75.0	66.7
2-3 KM	85	60.0	41.2	38.8	35.3
3-4 KM	71	53.5	39.4	32.4	23.9
4-5 KM	67	19.4	7.5	7.5	4.5
>5 KM	10	10.0	0.0	0.0	0.0

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	74	79.1	73.0	68.9	39.2
2-3 KM	105	72.4	48.6	42.9	21.9
3-4 KM	122	65.6	38.5	32.8	24.6
4-5 KM	120	22.5	8.3	5.8	4.2
>5 KM	55	12.7	7.3	5.5	1.8

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	55	81.8	78.2	78.2	70.9
2-3 KM	112	69.6	56.3	52.7	44.6
3-4 KM	94	78.7	57.4	52.1	34.0
4-5 KM	112	47.3	27.7	22.3	16.1
>5 KM	75	29.3	13.3	12.0	9.3

TABLE: B-4 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: AN/TAS-4 TOW NIGHT SIGHT (SERIAL # 364A)

TARGET: M-651 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	69	62.3	43.5	39.1
2-3 KM	85	44.7	25.9	21.2
3-4 KM	112	33.9	17.9	8.9
4-5 KM	100	10.0	3.0	1.0
>5 KM	44	15.9	4.5	4.5

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	35	82.9	71.4	71.4
2-3 KM	65	84.6	73.8	58.5
3-4 KM	62	91.9	82.3	67.7
4-5 KM	72	45.8	30.6	18.1
>5 KM	23	26.1	13.0	4.3

TARGET: M-35 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	72	95.8	86.1	80.6
2-3 KM	101	82.2	68.3	58.4
3-4 KM	111	67.6	57.7	41.4
4-5 KM	85	49.4	37.6	25.9
>5 KM	57	35.1	28.1	21.1

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	52	67.3	30.8	25.0
2-3 KM	73	52.1	30.1	24.7
3-4 KM	60	46.7	23.3	21.7
4-5 KM	43	11.65	4.7	2.3
>5 KM	NO TARGETS AT THIS RANGE			

TABLE B-5

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: AN/TAS-4 TOW NIGHT SIGHT W/DISABLED SCAN LINES (SERIAL # FAT 2)

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	NO TARGETS AT THIS RANGE				
2-3 KM	24	58.3	45.8	41.7	25.0
3-4 KM	24	50.0	33.3	29.2	25.0
4-5 KM	3	66.7	66.7	33.3	0.0
>5 KM	NO TARGETS AT THIS RANGE				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	14	78.6	50.0	50.0	50.0
2-3 KM	83	60.2	47.0	41.0	33.7
3-4 KM	80	40.0	27.5	21.2	15.0
4-5 KM	77	15.6	6.5	3.9	3.9
>5 KM	19	21.1	10.5	5.3	5.3

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	80	80.0	67.5	63.7	41.2
2-3 KM	114	67.5	43.9	43.0	23.7
3-4 KM	139	45.3	18.0	17.3	8.6
4-5 KM	142	16.2	4.2	3.5	2.1
>5 KM	51	13.7	5.9	5.9	5.9

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	67	65.7	62.7	61.2	55.2
2-3 KM	126	65.9	58.7	54.8	46.0
3-4 KM	107	61.7	41.1	37.4	22.4
4-5 KM	130	44.6	26.2	24.6	16.9
>5 KM	73	26.0	12.3	11.0	6.8

TABLE B-5 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: AN/TAS-4 TOW NIGHT SIGHT W/ DISABLED SCAN LINES (SERIAL # FAT 2)

TARGET: M-651 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	70	62.9	44.3	37.1
2-3 KM	106	40.6	17.9	13.2
3-4 KM	120	28.3	10.8	5.0
4-5 KM	104	18.3	1.9	0.0
>5 KM	56	10.7	1.8	0.0

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	32	78.1	78.1	78.1
2-3 KM	77	84.4	58.4	51.9
3-4 KM	67	86.6	67.2	58.2
4-5 KM	79	48.1	25.3	15.2
>5 KM	23	39.1	30.4	17.4

TARGET: M-35 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	81	90.1	86.4	82.7
2-3 KM	104	73.1	61.5	57.7
3-4 KM	116	58.6	49.1	37.1
4-5 KM	103	50.5	34.0	20.4
>5 KM	61	44.3	19.7	8.2

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	50	62.0	28.0	28.0
2-3 KM	79	59.5	31.6	25.3
3-4 KM	72	41.7	18.1	13.9
4-5 KM	57	14.0	5.3	5.3
>5 KM	NO TARGETS AT THIS RANGE			

FIGURE B-1
ALL TARGETS

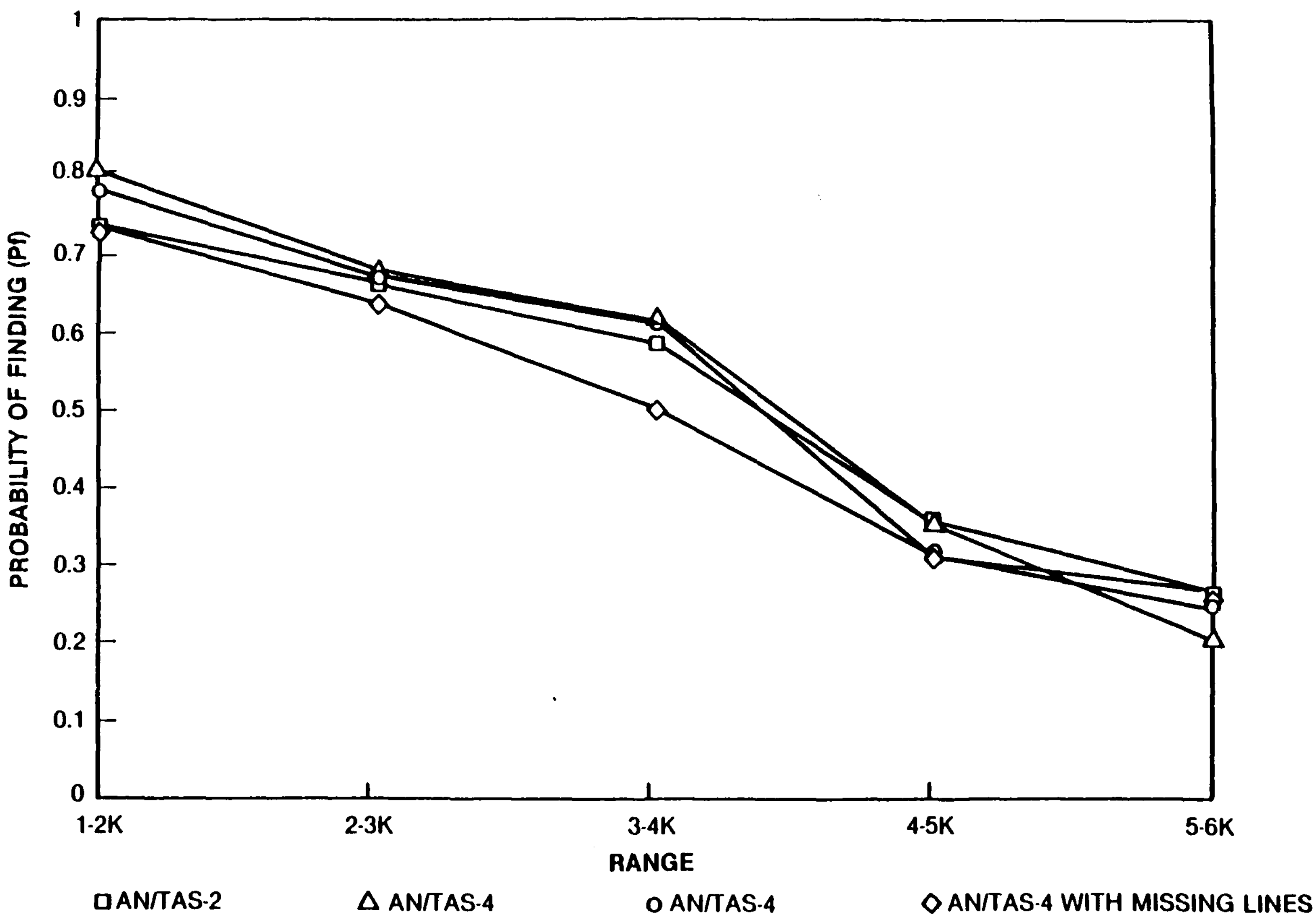


FIGURE B-2
ALL TARGETS

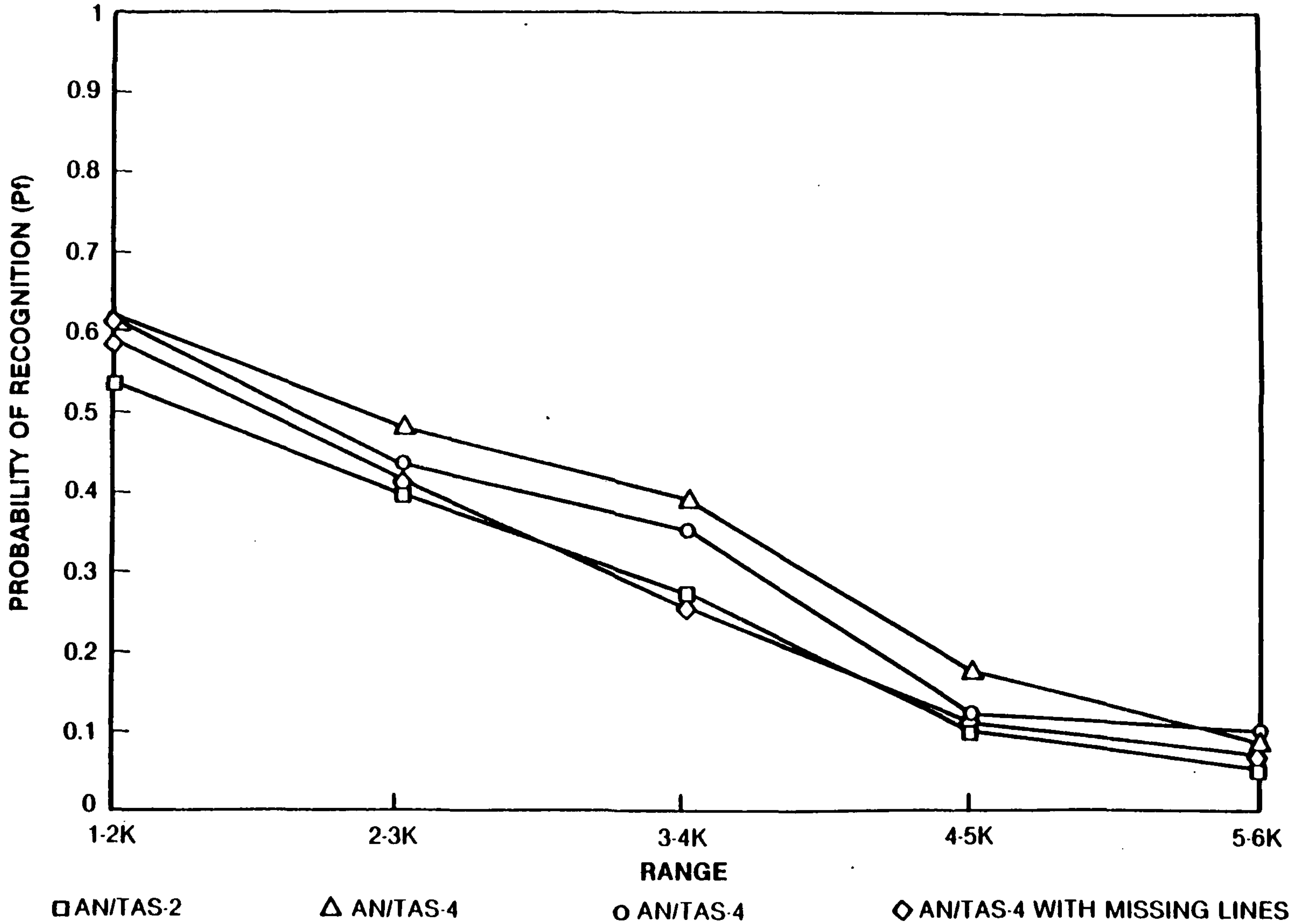


FIGURE B-3
ALL TARGETS

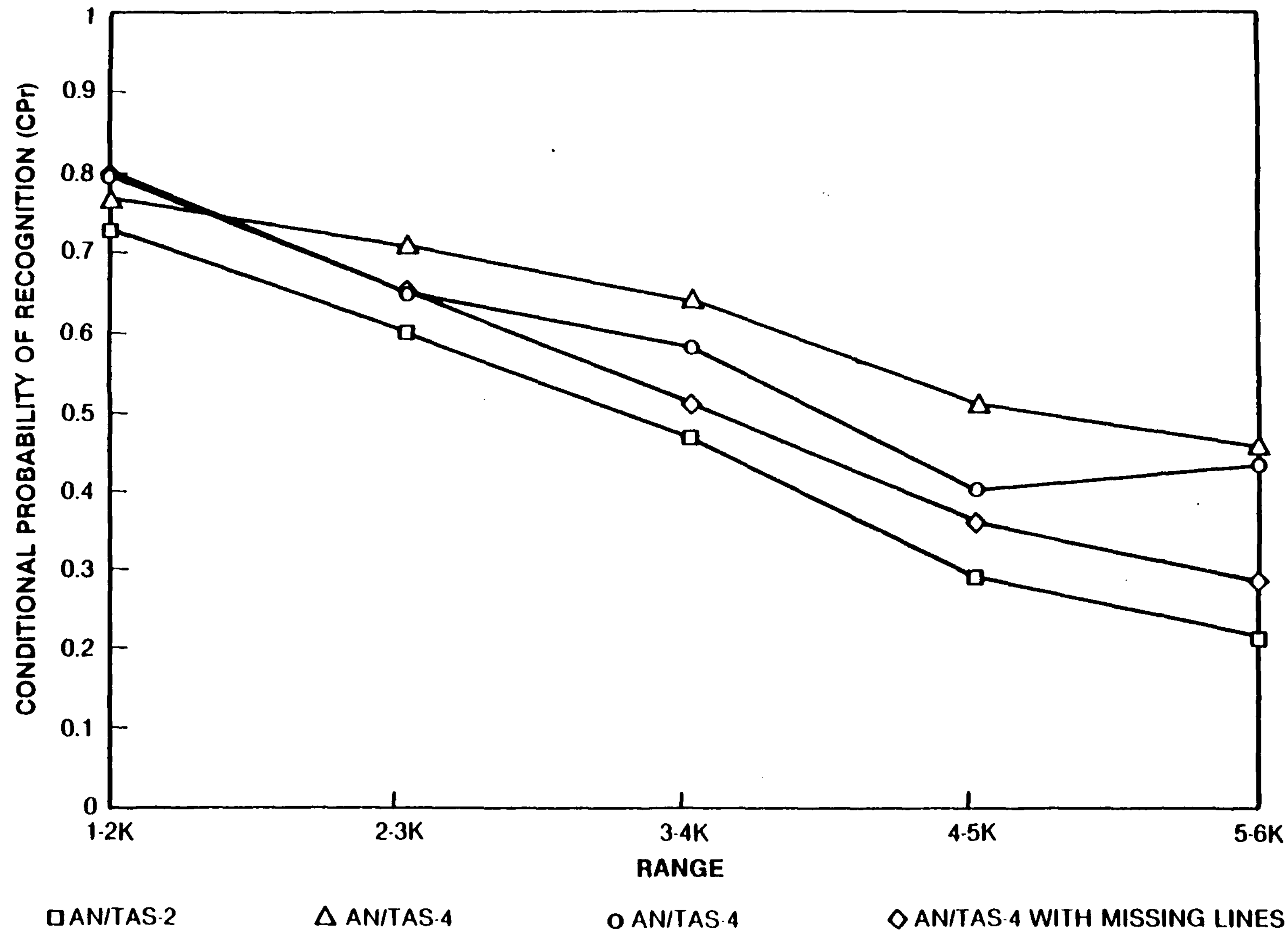


TABLE: B-6

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: AN/VSG-2 TANK THERMAL SIGHT "WHITE HOT" (SERIAL # 013)

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	3	100.0	66.7	66.7	66.7
2-3 KM	21	71.4	66.7	66.7	47.6
3-4 KM	24	50.0	41.7	37.5	8.3
4-5 KM	6	16.7	16.7	16.7	16.7
>5 KM	--------NO TARGETS AT THIS RANGE--------------------				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	14	92.9	78.6	78.6	71.4
2-3 KM	89	59.6	47.2	34.8	32.6
3-4 KM	76	56.6	32.9	27.6	21.1
4-5 KM	79	13.9	6.3	5.1	2.5
>5 KM	16	12.5	0.0	0.0	0.0

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	77	75.3	55.8	55.8	42.9
2-3 KM	115	78.3	57.4	53.9	40.9
3-4 KM	137	69.3	34.3	32.1	26.3
4-5 KM	138	31.2	9.4	8.7	5.8
>5 KM	56	17.9	3.6	3.3	3.6

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	64	78.1	76.6	75.0	65.6
2-3 KM	124	76.6	62.1	62.1	50.0
3-4 KM	109	78.0	59.6	53.2	31.2
4-5 KM	129	52.7	27.9	24.0	18.6
>5 KM	76	26.3	9.2	6.6	3.9

TABLE B-6 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: AN/VSG-2 TANK THERMAL SIGHT "WHITE HOT" (SERIAL # 013)

TARGET: M-651 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	76	71.1	63.2	57.9
2-3 KM	101	50.5	25.7	23.8
7 3-4 KM	120	40.0	19.2	9.2
4-5 KM	103	22.3	6.8	1.0
>5 KM	53	9.4	3.8	3.8

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	35	74.3	68.6	62.9
2-3 KM	74	86.5	74.3	59.5
3-4 KM	70	94.3	77.1	64.3
4-5 KM	79	51.9	38.0	29.1
>5 KM	23	43.5	39.1	13.0

TARGET: M-35 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	81	90.1	86.4	77.8
2-3 KM	105	76.2	67.6	56.2
3-4 KM	118	71.2	50.0	37.3
4-5 KM	103	61.2	36.9	23.3
>5 KM	59	54.2	37.3	23.7

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	53	68.8	50.9	45.3
2-3 KM	81	70.4	45.7	37.0
3-4 KM	69	52.2	24.6	20.3
4-5 KM	55	18.2	9.1	3.6
>5 KM	---------NO TARGETS AT THIS RANGE------------------			

TABLE B-7

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: AN/VSG-2 TANK THERMAL SIGHT "BLACK HOT" (SERIAL # 003)

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	NO TARGETS AT THIS RANGE				
2-3 KM	15	86.7	80.0	80.0	53.3
3-4 KM	22	31.8	31.8	31.8	22.7
4-5 KM	3	66.7	66.7	66.7	66.7
>5 KM	NO TARGETS AT THIS RANGE				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	12	91.7	50.0	41.7	41.7
2-3 KM	69	68.1	46.4	39.1	31.9
3-4 KM	74	47.3	31.1	24.3	17.6
4-5 KM	77	26.0	6.5	3.9	2.6
>5 KM	10	20.0	10.0	0.0	0.0

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	65	78.5	41.5	36.9	27.7
2-3 KM	105	56.2	38.1	35.2	21.0
3-4 KM	134	63.4	32.1	29.9	23.1
4-5 KM	131	17.6	6.1	6.1	4.6
>5 KM	37	18.9	5.4	5.4	2.7

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	67	76.1	71.6	71.6	64.2
2-3 KM	110	72.7	55.5	50.9	39.1
3-4 KM	89	60.7	36.0	33.7	21.3
4-5 KM	117	41.9	27.4	23.1	11.1
>5 KM	68	20.6	10.3	8.8	2.9

TABLE B-7 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: AN/VSG-2 TANK THERMAL SIGHT "BLACK HOT" (SERIAL # 003)

TARGET: M-651 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	60	63.3	43.3	33.3
2-3 KM	97	46.4	23.7	16.5
3-4 KM	110	33.6	13.6	7.3
4-5 KM	102	15.7	3.9	2.0
>5 KM	38	10.5	0.0	0.0

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	29	86.2	79.3	69.0
2-3 KM	69	75.4	49.3	37.7
3-4 KM	64	84.4	65.6	48.4
4-5 KM	65	53.8	18.5	4.6
>5 KM	23	26.1	13.0	8.7

TARGET: M-35A2 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	76	85.5	67.1	51.3
2-3 KM	93	77.4	54.8	44.1
3-4 KM	100	63.0	42.0	38.0
4-5 KM	100	43.0	23.0	15.0
>5 KM	57	40.4	19.3	8.8

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	42	81.0	54.8	52.4
2-3 KM	76	55.3	38.2	31.6
3-4 KM	69	33.3	23.2	15.9
4-5 KM	39	10.3	7.7	7.7
>5 KM	------NO TARGETS AT THIS RANGE------			

FIGURE B-4

ALL TARGETS

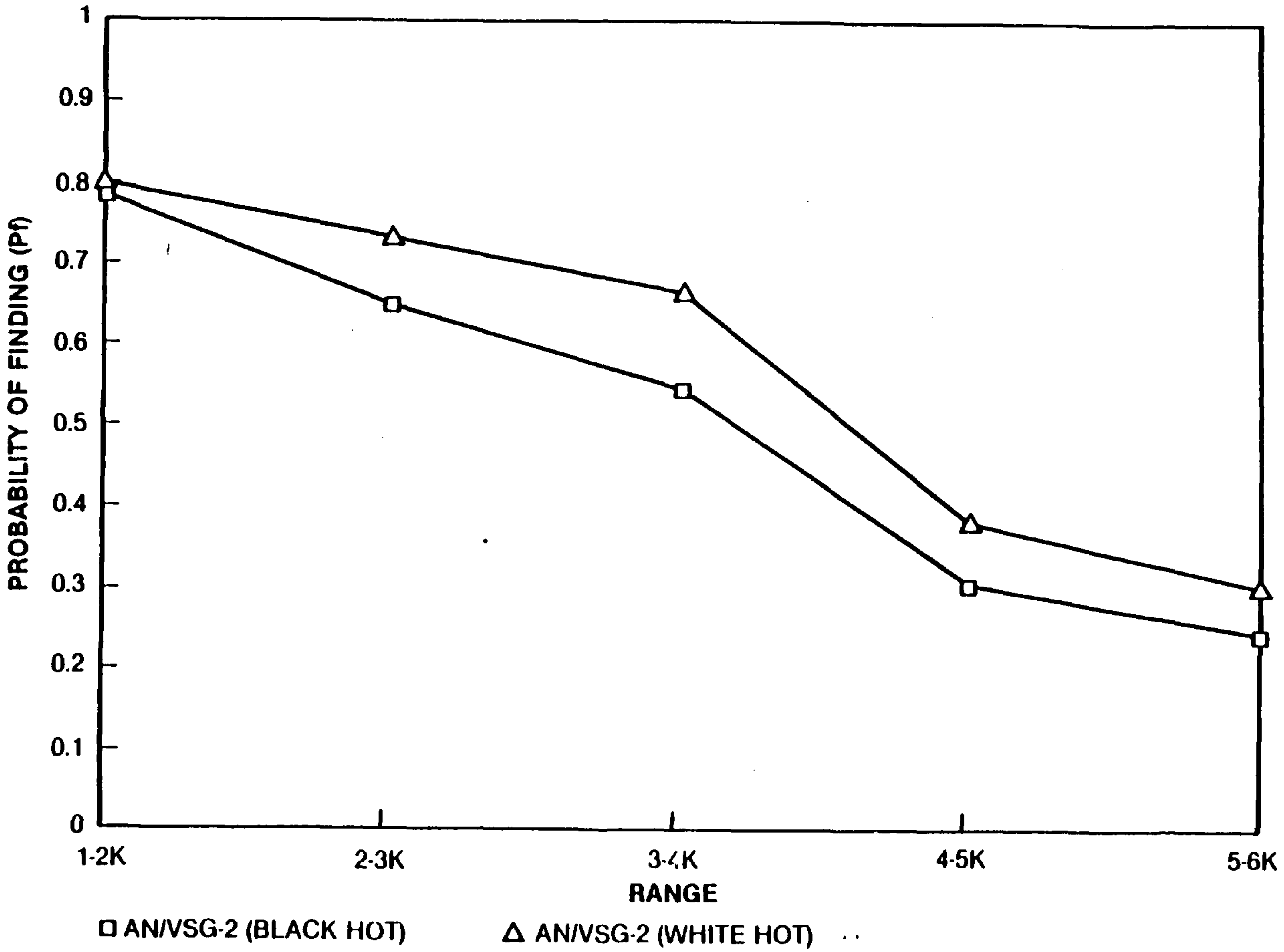


FIGURE B-5

ALL TARGETS

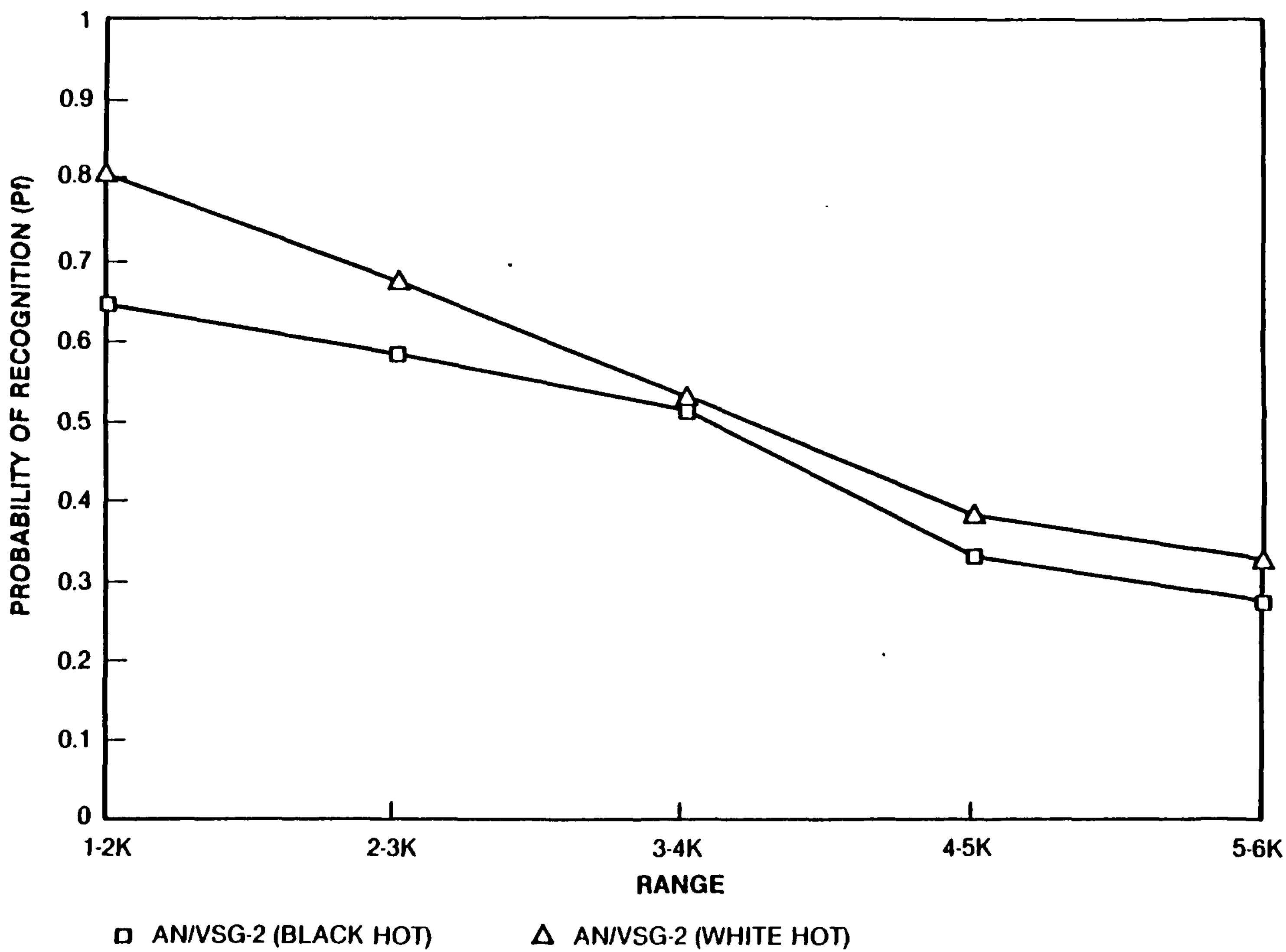


FIGURE B-6
ALL TARGETS

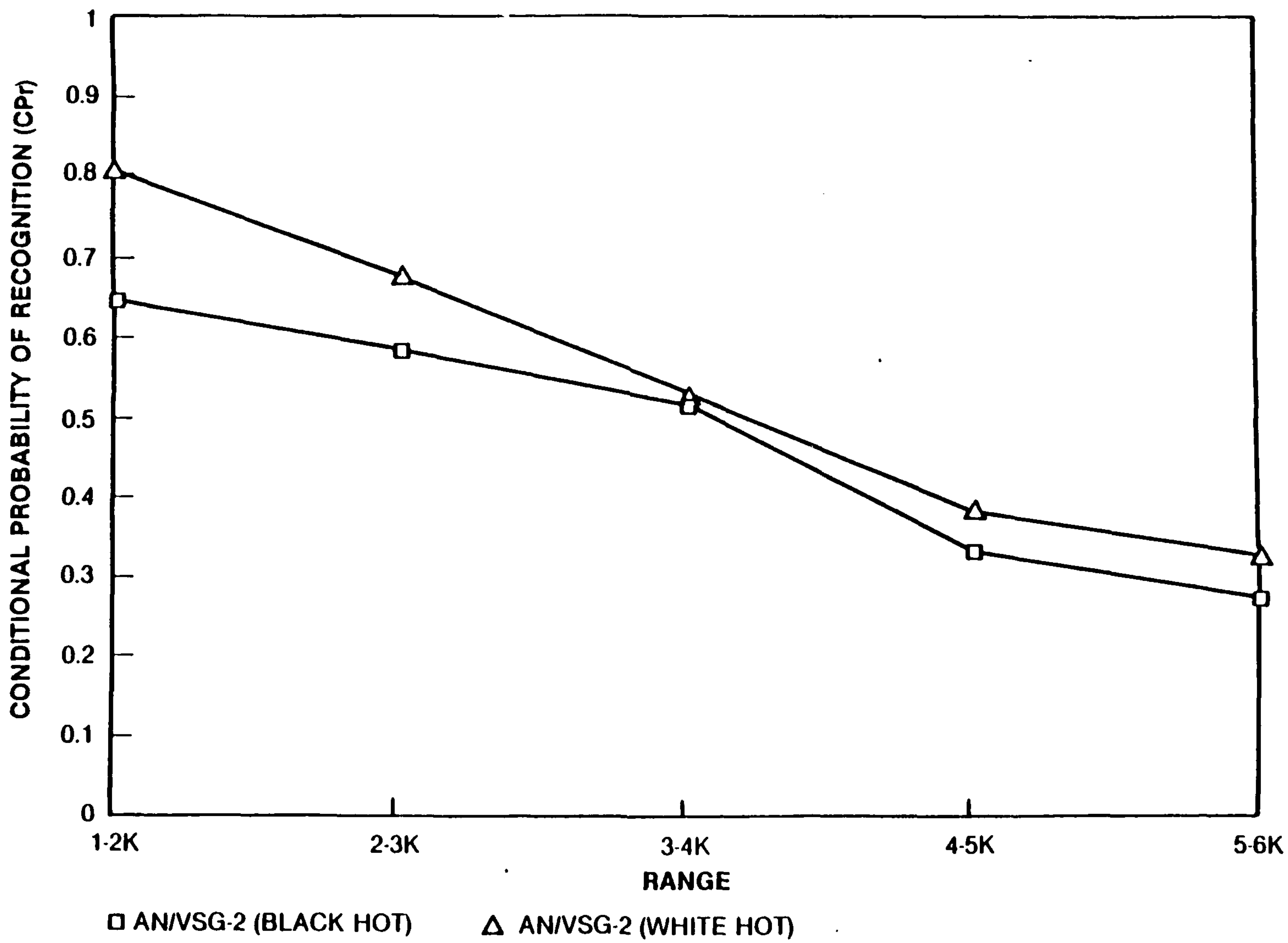


TABLE B-8

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: TOW DAY OPTICS

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	5	100.0	100.0	100.0	100.0
2-3 KM	21	71.4	66.7	66.7	57.1
3-4 KM	13	69.2	46.2	46.2	46.2
4-5 KM	8	62.5	50.0	50.0	50.0
>5 KM	---------------NO TARGETS AT THIS RANGE----------				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	--------------NO TARGETS AT THIS RANGE-----------				
2-3 KM	59	66.1	54.2	49.2	45.8
3-4 KM	60	50.0	36.7	33.3	26.7
4-5 KM	57	26.3	15.8	10.5	8.8
>5 KM	6	33.3	0.0	0.0	0.0

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	37	45.9	37.8	37.8	35.1
2-3 KM	78	35.9	24.4	23.1	14.1
3-4 KM	86	27.9	16.3	11.6	5.8
4-5 KM	102	5.9	1.0	1.0	0.0
>5 KM	27	0.0	0.0	0.0	0.0

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	40	42.5	42.5	42.5	32.5
2-3 KM	100	40.0	36.0	32.0	26.0
3-4 KM	72	29.2	20.8	18.1	11.1
4-5 KM	67	14.9	3.0	3.0	0.0
>5 KM	47	14.9	10.6	10.6	0.0

TABLE B-8 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: TOW DAY OPTICS

TARGET: M-561 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	72	68.1	51.4	40.3
2-3 KM	71	46.5	25.4	11.3
3-4 KM	67	43.3	28.4	16.4
4-5 KM	54	29.6	11.1	5.6
>5 KM	24	16.7	12.5	0.0

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	21	61.9	52.4	52.4
2-3 KM	43	65.1	58.1	58.1
3-4 KM	34	64.7	52.9	35.3
4-5 KM	58	44.8	22.4	20.7
5 KM	23	26.1	8.7	8.7

TARGET: M-35A-2 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	48	81.3	75.0	72.9
2-3 KM	63	52.4	36.5	33.3
3-4 KM	85	56.5	36.5	30.6
4-5 KM	68	32.4	14.1	10.3
>5 KM	48	10.4	4.2	4.2

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	28	75.0	64.3	60.7
2-3 KM	36	61.1	36.1	36.1
3-4 KM	57	28.1	19.3	19.3
4-5 KM	41	9.8	0.0	0.0
>5 KM	9	11.1	0.0	0.0

TABLE B-9

TARGET PROBABILITIES VS RANGE (ARMORED VEHICLES)

SYSTEM: SILICON TELEVISION

TARGET: M-60 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	-----------NO TARGETS AT THIS RANGE-----------------				
2-3 KM	9	77.8	66.7	66.7	66.7
3-4 KM	4	75.0	75.0	75.0	75.0
4-5 KM	8	62.5	62.5	62.5	37.5
>5 KM	-----------NO TARGETS AT THIS RANGE-----------------				

TARGET: M-551 TANK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	14	85.7	78.6	78.6	78.6
2-3 KM	29	58.6	44.8	44.8	44.8
3-4 KM	17	52.9	52.9	52.9	52.9
4-5 KM	19	52.6	42.1	42.1	42.1
>5 KM	9	11.1	11.1	11.1	11.1

TARGET: M-113 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	24	91.7	87.5	87.5	83.3
2-3 KM	33	36.4	36.4	33.3	33.3
3-4 KM	33	57.6	54.5	54.5	51.5
4-5 KM	34	32.4	32.4	32.4	32.4
>5 KM	30	33.3	26.7	23.3	23.3

TARGET: M-577 APC

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	RECOG (%)	IDENT (%)
1-2 KM	21	81.0	81.0	81.0	81.0
2-3 KM	33	72.7	72.7	72.7	72.7
3-4 KM	42	42.9	40.5	40.5	38.1
4-5 KM	43	39.5	34.9	34.9	30.2
>5 KM	23	56.5	56.5	56.5	56.5

TABLE B-9 (CONTINUED)

TARGET PROBABILITIES VS RANGE (WHEELED VEHICLES)

SYSTEM: SILICON TELEVISION

TARGET: M-651 GAMMA GOAT

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	32	71.9	65.6	65.6
2-3 KM	31	38.7	38.7	38.7
3-4 KM	21	23.8	19.0	14.3
4-5 KM	21	28.6	19.0	9.5
>5 KM	28	17.9	10.7	7.1

TARGET: M-656 5 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	3	100.0	100.0	100.0
2-3 KM	22	72.7	68.2	63.6
3-4 KM	15	73.3	53.3	53.3
4-5 KM	41	58.5	51.2	48.8
>5 KM	NO TARGETS AT THIS RANGE			

TARGET: M-35 2 1/2 TON TRUCK

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	18	55.6	55.6	55.6
2-3 KM	28	67.9	67.9	64.3
3-4 KM	40	57.5	55.0	55.0
4-5 KM	25	28.0	12.0	12.0
>5 KM	14	64.3	64.3	64.3

TARGET: M-151 1/4 TON TRUCK (JEEP)

RANGE (METERS)	TOTAL TGTS	FIND (%)	CLASS (%)	IDENT (%)
1-2 KM	27	63.0	55.6	55.6
2-3 KM	26	46.2	46.2	46.2
3-4 KM	12	16.7	16.7	16.7
4-5 KM	21	9.5	9.5	9.5
>5 KM	9	0.0	0.0	0.0

FIGURE B-7
ALL TARGETS

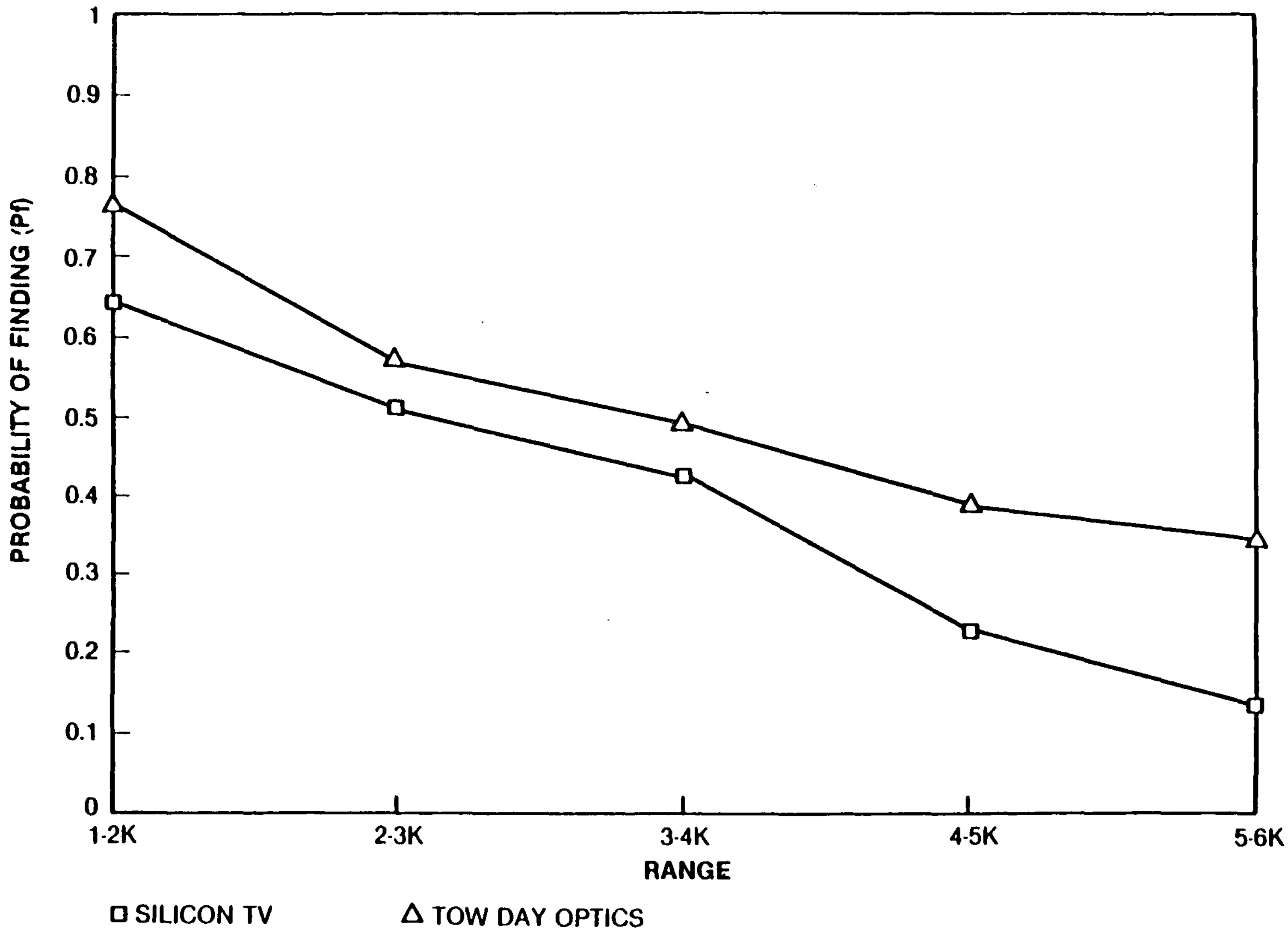


FIGURE B-8
ALL TARGETS

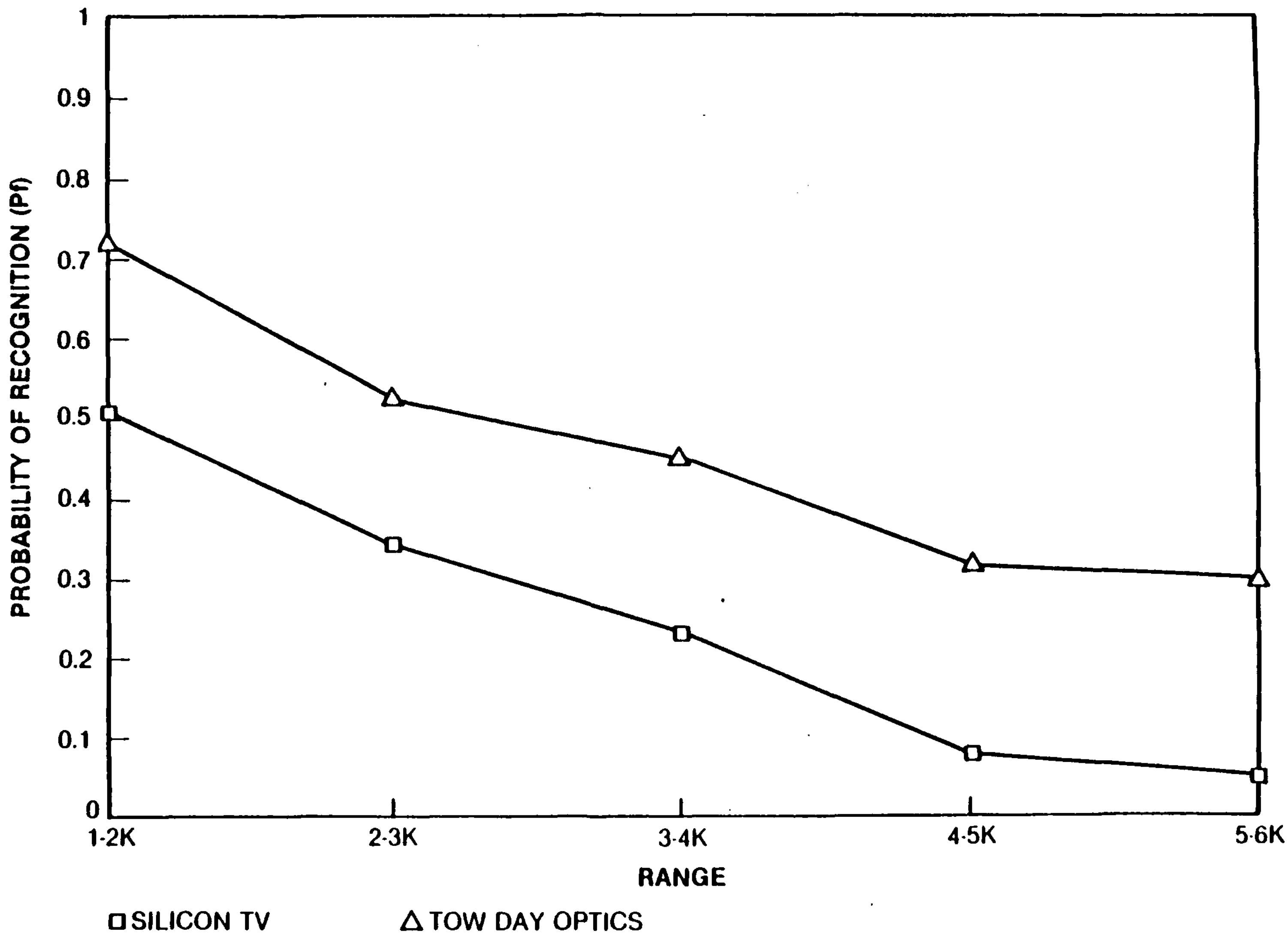


FIGURE B-9
ALL TARGETS

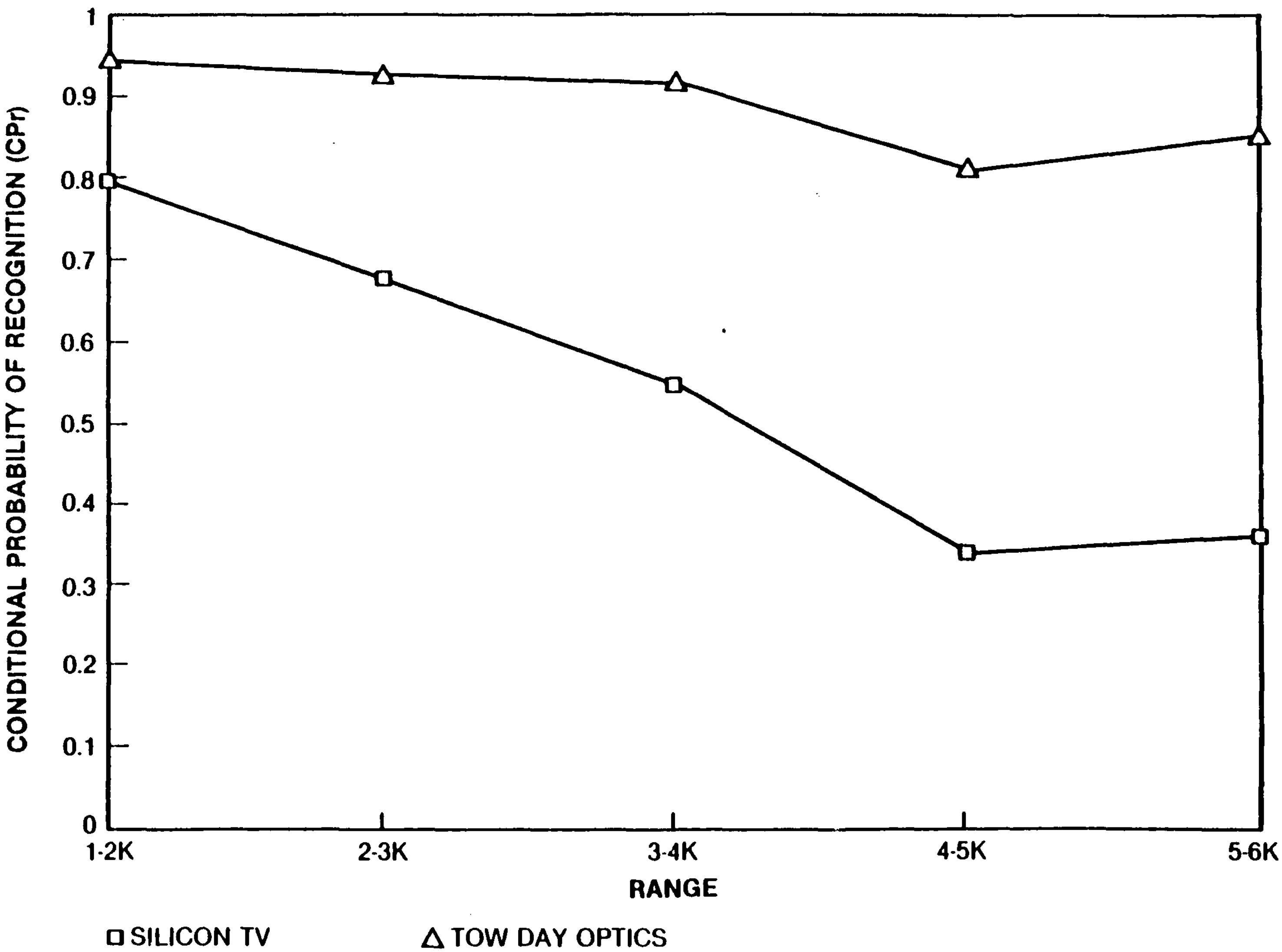


TABLE B-10

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: AN/TAS-2 3 TO 5 um THERMAL IMAGER

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	.90	.10	.00	.00	.00	.00	.00	.00	21
M551	.09	.69	.04	.09	.03	.00	.01	.05	77
M113	.01	.05	.38	.26	.13	.14	.01	.02	170
M577	.00	.02	.15	.72	.04	.03	.04	.00	185
M35	.00	.02	.04	.06	.69	.14	.03	.02	234
M656	.00	.03	.01	.02	.30	.60	.01	.03	164
M151	.00	.01	.05	.22	.01	.03	.67	.01	78
GG	.00	.04	.10	.06	.16	.07	.03	.54	91

N* is the total number of identification responses.

TABLE B-11

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: AN/TAS-4 TOW NIGHT SIGHT (SERIAL # 545

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	.70	.24	.03	.00	.00	.00	.00	.03	33
M551	.06	.71	.06	.03	.07	.03	.02	.02	108
M113	.00	.02	.54	.16	.11	.11	.02	.04	234
M577	.00	.01	.13	73	.03	.04	.03	.03	263
M35	.00	.00	.01	.04	.84	.10	.00	.01	276
M656	.00	.00	.01	.03	.18	.77	.00	.02	190
M151	.01	.01	.09	.06	.01	.02	.77	.03	109
GG	.00	.04	.11	.05	.09	.07	.01	.63	91

N* is the total number of identification responses.

TABLE B-12

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: AN/TAS-4 TOW NIGHT SIGHT (SERIAL # 364-A)

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	.44	.39	.11	.00	.06	.00	.00	.00	18
M551	.05	.72	.07	.09	.04	.00	.01	.02	81
M113	.01	.03	.51	.20	.12	.07	.03	.03	174
M577	.00	.02	.12	.72	.06	.01	.04	.01	203
M35	.01	.00	.03	.01	.80	.11	.01	.03	246
M656	.00	.00	.01	.03	.15	.76	.01	.04	158
M151	.01	.00	.10	.22	.03	.01	.58	.04	77
GG	.02	.04	.10	.04	.09	.09	.06	.56	102

N* is the total number of identification responses.

TABLE B-13

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: AN/TAS-4 TOW NIGHT SIGHT W/ DISABLED SCAN LINES (SERIAL # FAT-02)

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	.55	.23	.05	.09	.05	.05	.00	.00	22
M551	.08	.68	.08	.07	.07	.00	.03	.00	75
M113	.01	.02	.46	.24	.12	.12	.02	.02	171
M577	.00	.00	.13	.73	.01	.03	.06	.02	201
M35	.00	.00	.03	.04	.78	.13	.00	.02	251
M656	.00	.01	.02	.04	.15	.75	.00	.03	160
M151	.01	.04	.10	.21	.05	.00	.57	.02	82
GG	.01	.03	.11	.04	.12	.15	.05	.49	94

N* is the total number of identification responses.

TABLE B-14

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: AN/VSG-2 THERMAL TANK SIGHT "WHITE HOT" (SERIAL # 013)

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	.64	.32	.00	.00	.00	.00	.00	.04	28
M551	.04	.65	.10	.10	.05	.02	.02	.02	94
M113	.00	.01	.57	.13	.09	.10	.04	.05	225
M577	.01	.00	.14	.70	.08	.05	.03	.00	239
M35	.00	.00	.01	.03	.75	.18	.00	.02	275
M656	.00	.01	.04	.01	.15	.76	.00	.03	181
M151	.00	.00	.09	.16	.03	.03	.68	.02	108
GG	.00	.02	.10	.06	.07	.08	.05	.62	133

N* is the total number of identification responses.

TABLE B-15

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: AN/VSG-2 TANK THERMAL SIGHT "BLACK HOT" (SERIAL # 003)

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	.71	.29	.00	.00	.00	.00	.00	.00	21
M551	.05	.57	.04	.08	.09	.03	.08	.05	74
M113	.00	.02	.47	.16	.10	.15	.05	.05	167
M577	.01	.01	.18	.62	.04	.04	.08	.02	193
M35	.01	.02	.05	.07	.62	.17	.01	.05	217
M656	.01	.01	.07	.03	.27	.54	.01	.06	151
M151	.00	.00	.11	.06	.02	.02	.75	.02	80
GG	.00	.01	.16	.02	.12	.16	.09	.45	102

N* is the total number of identification responses.

TABLE B-16

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: SILICON TELEVISION

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	.93	.03	.03	.00	.00	.00	.00	.00	29
M551	.095	.79	.02	.03	.08	.02	.00	.02	61
M113	.00	.02	.64	.18	.09	.02	.02	.02	45
M577	.02	.03	.16	.73	.02	.03	.02	.00	64
M35	.01	.03	.09	.04	.80	.00	.01	.02	113
M656	.00	.00	.08	.03	.05	.78	.01	.05	79
M151	.00	.02	.02	.12	.00	.02	.82	.00	50
GG	.00	.02	.07	.01	.20	.14	.01	.54	94

N* is the total number of identification responses.

TABLE B-17

PROBABILITY OF TARGET IDENTIFICATION RESPONSE - CORRECT AND INCORRECT - FOR EACH SYSTEM AND EACH TARGET AT ALL RANGES

SENSOR: TOW DAY OPTICS

TARGET	IDENTIFICATION PROBABILITIES								
	M60	M551	M113	M577	M35	M656	M151	GG	N*
M60	1.00	.00	.00	.00	.00	.00	.00	.00	12
M551	.00	.92	.00	.04	.00	.04	.00	.00	48
M113	.00	.00	.97	.03	.00	.00	.00	.00	68
M577	.00	.00	.02	.97	.00	.00	.00	.01	86
M35	.00	.00	.00	.00	.98	.02	.00	.00	63
M656	.00	.00	.00	.00	.04	.92	.02	.02	49
M151	.00	.00	.00	.00	.00	.00	1.00	.00	32
GG	.00	.00	.00	.02	.09	.02	.02	.85	47

N* is the total number of identification responses.

APPENDIX C
TARGET SIGNATURE MEASUREMENTS

PROCEDURE

The target signatures were measured in three spectral regions; visible (0.4 to 0.7μm), silicon (0.73 to 0.7μm), and 8 to 12μm. Equipment was not available to measure the 3 to 5μm target signatures. The target signatures were measured for every target vehicle at least once during each trial, except for a few days when the visible and silicon target contrast was measured during alternate trials. Data reduction was performed on site during and immediately after each trial.

The sensors used to collect the target signature imagery were mounted on a servo driven platform and boresighted to a common aim point. A matrix was provided for each trial that included the azimuth and elevation, with respect to the target signature sensors, to permit the sensor operators to quickly select the targets.

MEASUREMENT EQUIPMENT

Visible: RCA TV Camera with photopic filter and Nikon 200 to 600mm lens.

Silicon: RCA Silicon TV Camera with 0.73 to 1.0μm filter and Nikon 200 to 600mm lens.

8 to 12μm: Ford Aerospace Calibrated Infrared Imager, Model DL-1, with two internal blackbodies.

IFOV - 0.1 mrad
FOV - 1.0 to 7.0 degrees (zoom lens)

The imagery from each of the sensors was recorded on a Panasonic NV-2000A video recorder. IRIG-B time code was recorded with the DL-1 8 to 12μm imagery; time code alphanumeric generators were used to record date/time on the visible and silicon camera imagery.

The following equipment was used for data reduction of the target signature imagery:

Tektronic 1480 Waveform Monitor
Panasonic 9-inch Video Monitor
Quantex DS-30 Digital Image Processor

A Hewlett-Packard HP-85 computer was used to calculate the 8 to 12μm target delta T.

DATA REDUCTION

The data reduction techniques for the visible and silicon target signatures were the same and were as follows:

- A single frame of imagery was selected and stored by the DS-30 digital image processor and input to a 1480 waveform monitor and a video monitor. The output image was DC restored to the backdoor of the horizontal TV synchronization pulse.

- Selected individual lines that subtended both the target and background were analyzed using the single line function of the waveform monitor. The synchronization pulse voltage of the target and background of the selected lines were measured. The measured voltage values were used to determine the apparent contrast ratio as:

$$\text{Contrast Ratio} = \frac{\text{Target - Background}}{\text{Background}}$$

The 8 to 12μm target signature data reduction techniques were as follows:

- One video output of the DL-1 infrared imager was input to a 1480 waveform monitor and a TV monitor to insure that the DL-1 imager was working within the linear response of the sensor.

- A second video output from the DL-1 was input through a TV monitor to a video recorder to record both the DL-1 imagery and the IRIG-B time code to permit data reduction at a later time, if required.

- A third video output of the DL-1 was input to a DS-30 digital image processor. The output of the image processor was input to a second 1480 waveform monitor and to a video monitor.

- The digital image processor was set to the averaging mode to improve the signal/noise of the DL-1 imagery. Several frames of target imagery were then input to the digital image processor.

- The waveform monitor was set to the single line function. In this mode, each line that subtends the target scans both blackbodies. Since the temperatures of the blackbodies are known, a direct read out of the internal target temperature and background temperature is made possible. The target and background values were input to the HP-85 computer to sum the values, and added to the target weighting factors to calculate the target delta t.

RESULTS

- Visible Contrast. A sampling of 100 signatures that were measured over several days indicated that the visible contrast ratio of most of the targets was between -0.40 and -0.60. This corresponded to a high target-to-background contrast. Approximately 15% of the signatures sampled had a contrast ratio of less than -0.40 and about -10% were greater than -0.60.

- Silicon Contrast. A sampling of the silicon contrast data indicated that 65% of the targets had a contrast ratio of between -0.15 and -0.40; 20% were between -0.05 and -0.15, while 15% where greater than -0.40. These data indicated that the silicon target-to-background contrast was medium to high. Note that a negative value, for both the visible and silicon target signature measurements, indicated a target darker than the background. Very few targets measured had a positive contrast value.

- 8 to 12μm Target Signatures. Two samples of 100 measurements each were made. The signatures were measured over a period of several days. The first sample was for trials conducted between the hours of 0900 and 1100. The second sample was for trials that took place between 1300 and 1500 hours. The two samples were reduced to histograms and the means and standard deviations were calculated. Both samples covered a similar delta t range; however, the afternoon sample indicated a mean of 3.67°C, while the morning sample mean was 2.32°C. In both cases, the standard deviation was greater than 80% of the mean value. The morning measurements showed a median delta t of 1.75° versus a median of 3.20° in the afternoon. Thus, these data indicated that the targets had a higher contrast overall in the afternoon than could be expected in the late morning hours. Figures C-1 and C-2 show the delta t histograms for morning and afternoon measurements.

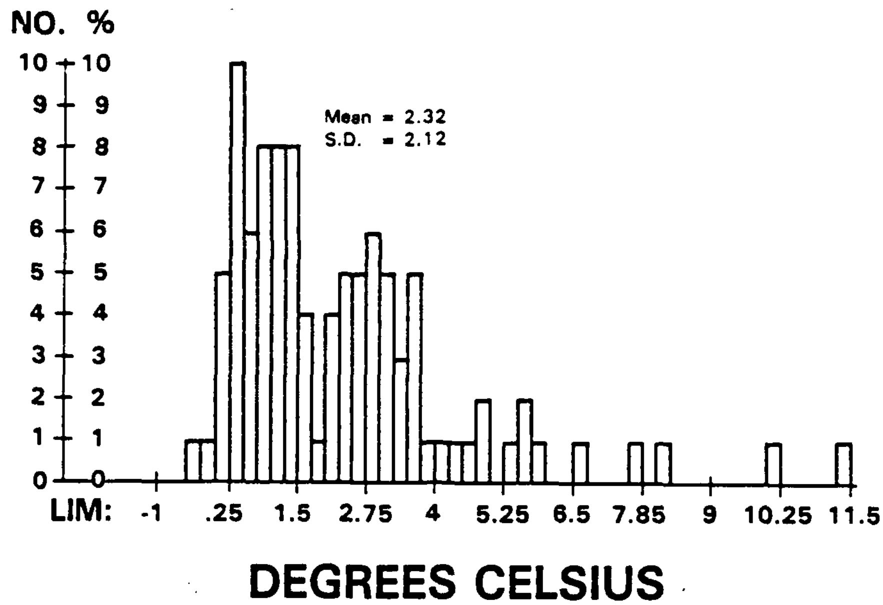


Figure C-1. 8 to 12μm Target Signature Histogram, Morning

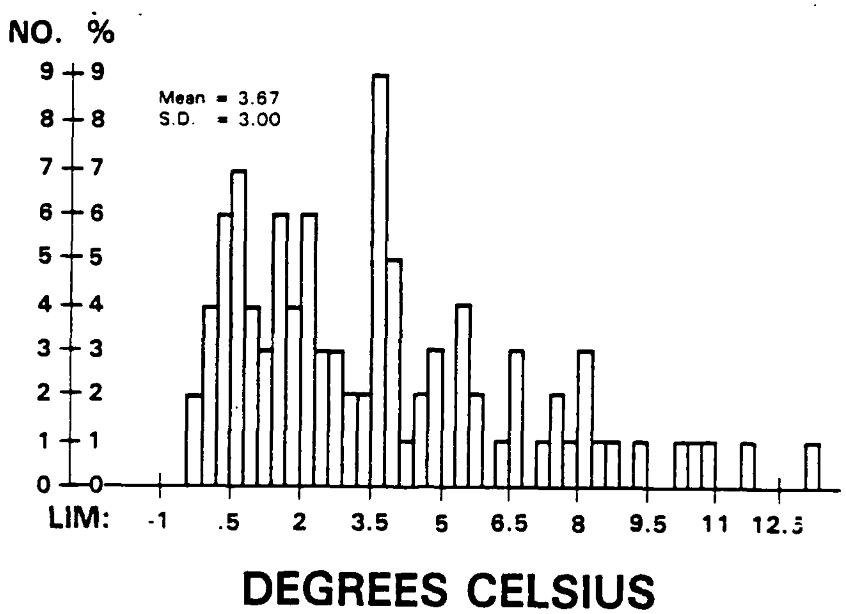


Figure C-2. 8 to 12μm Target Signature Histogram, Afternoon

APPENDIX D
METHODOLOGY
Developed for the Obscurant and Clear Air Trials of the Smoke 5-B Field Test

NOTE: The methodology included in this appendix was published in the proceedings of VIII Smoke Symposium. It is included here in its entirety.

ABSTRACT

The purpose of the Smoke 5-B field test was to determine the search effectiveness of a variety of night vision and electro-optical sensors in clear and obscured environments. This required that several recently developed data acquisition components be successfully integrated into a functioning system. The resulting system contributed greatly to the successful acquisition of search data at the Smoke 5-B test. This paper presents a description of the unique range lay-out methodology and data acquisition system used at the Smoke 5-B search test. Included are descriptions of (1) automated meteorological capabilities, (2) range lay-out and target matrix methods, (3) target tracking system, (4) sensor tracking system, (5) observer response recording, (6) AUTOFEDS computer, and (7) target signature methodology. The advantages of this system and its potential in future tests are discussed.

1.0 BACKGROUND:

The Project Manager Smoke and Obscurants (PM-S) at Aberdeen Proving Ground, MD, sponsored and provided funding to the Center for Night Vision and Electro-Optics (CNVEO), Fort Belvoir, VA, to design, implement, and conduct a field experiment to investigate the effects of obscurants on search and acquisition. The test was conducted during October through November 1983 at Fort Huachuca, AZ.

2.0 INTRODUCTION:

The Smoke 5-B experiment was designed to determine the search effectiveness of a variety of night vision and electro-optical sensors in clear and obscured environments. Experimental data will aid in the validation of CNVEO search models and system performance models as well as provide indications of the effects of various obscurants. It should be noted that there was not a sufficient number of obscurant trials using any one obscurant or deployment technique to provide a reliable data base. On the other hand, the general effects of obscurants on sensor performance, including range for detection/recognition of targets and search technique were investigated by comparison of adjacent clear air with obscured air trials using a similar target/range array.

Performance measurements that were recorded for each sensor include:

1. Target detection and recognition range

2. Time to detect/recognize

3. Search pattern

4. Search rate

Atmospheric measurements, as applicable to day/night and/or clear and obscured environments, obscurant quantification measurements, and target signatures were made and collated to the system performance data. All recorded measurements and data were collated to IRIG-B timing.

3.0 TEST SUPPORT AND TEST SITE:

Test support was provided by the Field Engineering Branch, Electronic Proving Ground (EPG), Fort Huachuca, AZ. Support included target vehicles, drivers, and observer personnel, as well as logistics and materials.

The site selected for the Smoke 5-B experiment is on the West Range at Fort Huachuca, AZ. The range is grass covered rolling terrain with the major terrain undulation nearly parallel to the line of sight (LOS).

Foliage consists of deciduous trees restricted mainly to the areas adjacent to the major terrain undulations, with scattered similar trees and low bushes throughout most of the remaining area. Clutter, subjectively, appeared to be light to moderate, dependent upon the area. The clutter was "target competitive" in that no predominantly vertical vegetation is present. A line of telephone poles runs perpendicular to the LOS at a distance of about 1,000 meters from the apex of the search area, but these were not competitive to the acquisition of vehicle targets. The test site affords LOS to targets at ranges as great as 5.5km. A search fan of 60 degrees in azimuth was used for Smoke 5-B. A search fan of greater than 90 degrees is available.

A 180 feet by 160 feet fenced compound was installed by EPG for this experiment, as was an eight foot high platform, 60 feet long and eight feet wide, used for sensor deployment. Figure D-1 depicts the test range layout.

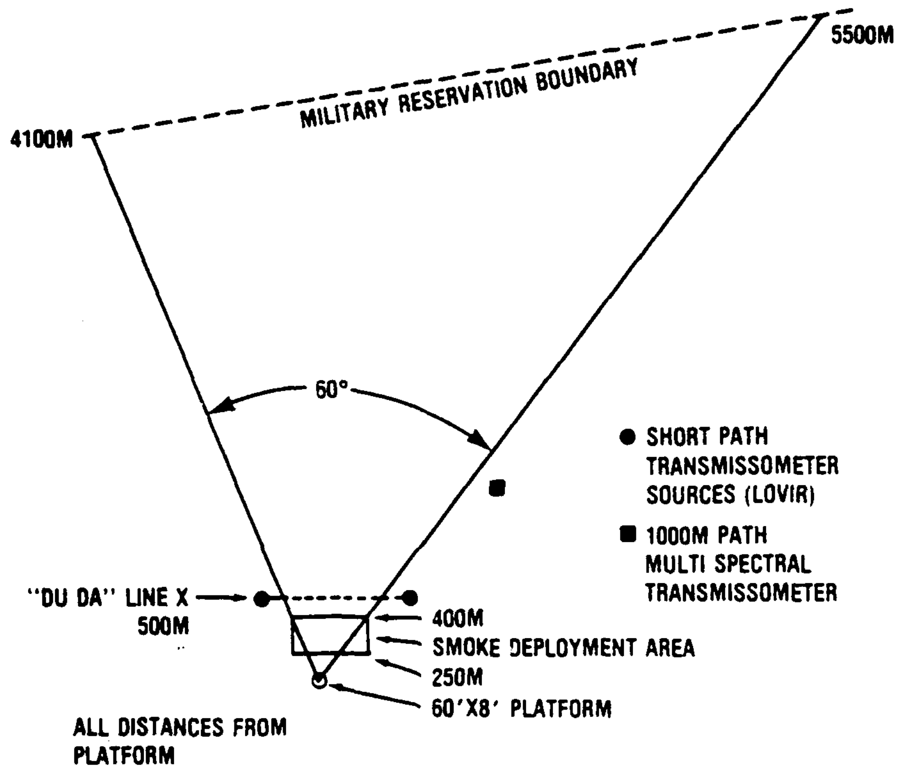


Figure D-1. Smoke 5-B Test Range Layout

4.0 TARGET VEHICLES:

The vehicles used as targets were selected from those that were available at Fort Huachuca. In addition, an M551 Tank and an M113 Armored Personnel Carrier were shipped to Fort Huachuca by CNVEO.

The target array included:

Quantity	Vehicle
3	M60A3 Tanks
1	M551 Tank
3	M113 APCs
2	M577 APCs
2	M561 Gamma Goats
1	M656 5 Ton Truck
2	M35A2 $2\frac{1}{2}$ Ton Trucks
1	M151 $\frac{1}{4}$ Ton Truck

A maximum of 15 target vehicles were available. Maintenance problems with the M60 tanks resulted in very few trials that included these vehicles.

5.0 SENSORS:

Nine sensors were available for performance evaluation. The sensors included:

Quantity Employed	Nomenclature
2	AN/VSG-2 Thermal Tank Sight (TTS)
3	AN/TAS-4 TOW Night Sights
1	AN/TAS-2 3 to 5μm Night Observation Device
1	Phillips 8 to 12μm Serial Scan Imager (Netherlands)
1	TOW Day Sight
1	Silicon TV

Several other sensors, notably the AN/VSG-2 and the AN/TAS-4 Night Sights, experienced short duration maintenance problems. However, in no case were all samples of these sensors out of service at the same time.

6.0 TEST RANGE LAYOUT:

The target positions within the 60 degree search fan are depicted on the test site map, Figure D-2. Note that the test fan was divided into five segments of 12 degrees each, i.e., A, B, C, D, and E, and that the target position identifiers include a letter followed by a two digit number, for example, A35. The identifier A35 indicates that the target is in the extreme left 12 degree segment and is 3,500 meters from the sensor array. The heavy black lines identify the major unsurfaced roads used to access the search fan. There are three North/South roads—Left, Center, and Right— and four East/West roads, identified for test purposes as the 1,100 Meter, 2,100 Meter, 3,500 Meter, and Perimeter Roads. (The Perimeter Road follows the fence line along the north boundary of the military reservation.)

The dotted lines originating from main roads are trails that were developed to provide access to target positions that were not readily accessible from the main roads. The circle and arrow symbols at the origin of trails depict sign locations. The signs include the target position(s) accessible from the particular trail and the direction. Although not shown, additional signs were used, as necessary, along the various trails.

All target positions were marked with the target position identifier, as were the defilade areas adjacent to the target positions. The position identifiers underlined (Figure D-2) are those positions that were easily seen from a main road. It should be emphasized that the vehicle operators had no difficulty in finding the correct target positions, per the matrix, throughout the experiment. Thus the rather elegant range layout eliminated a potential major source of delay in the conduct of the test. During the range set up, the experimenters documented the terrain and the immediate vicinity of each target position.

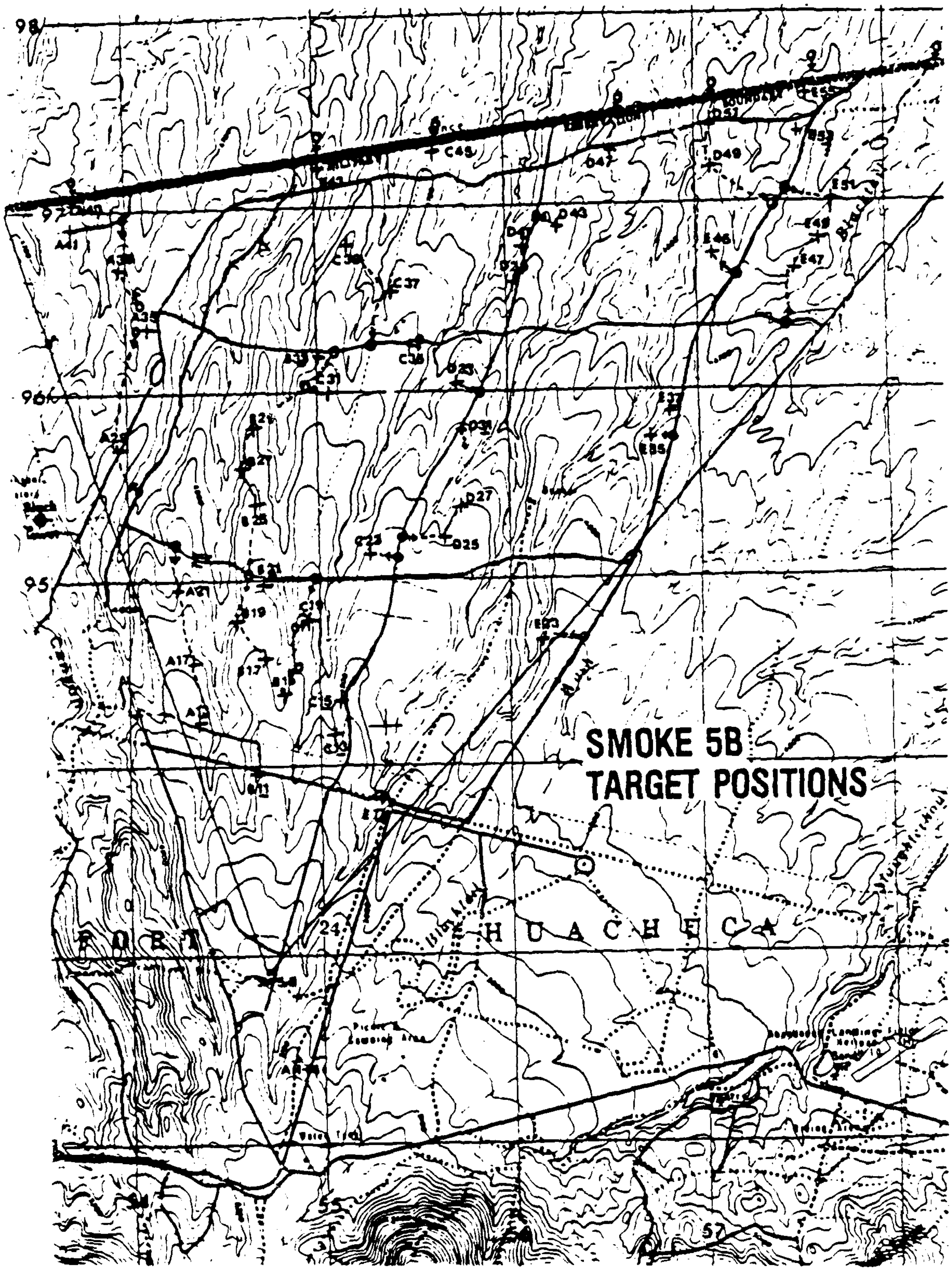


Figure D-2. Smoke 5-B Target Positions

7.0 TEST METHODOLOGY-MATRIX DESIGN:

A random target vehicle distribution matrix was designed for this experiment. The matrix "rules" were as follows:

1. Each trial consisted of 15 "events."

2. Each event consisted of 3 "cells."

3. Each event may consist of 0, 1, 2, or 3 targets within the search fan; therefore, there may be, conversely, 3, 2, 1, or 0 "No Target" cells.

4. A cell may require a target to be deployed, thus the cell would include: target type, target aspect, and target position azimuth. A cell may otherwise require that no target be deployed; in this case, the cell is simply designated "No Target."

5. No more than one target was permitted to appear in the same 12 degree segment (A, B, C, D, and E) within a single event and the target positions in adjacent 12 degree sectors were required to have a minimum separation of 6 degrees in azimuth. (This rule eliminated having more than one valid target appear within a sensor FOV, except by design).

6. No individual target vehicle was permitted to appear in consecutive events.

7. The number of replicates for each individual's target vehicle during a 15 event/45 cell matrix was controlled. Generally, a vehicle was not permitted to appear more than three times; vehicle types that were duplicated were usually limited to two replicates for one of the vehicles and three replicates for the other.

8. The number of "No Target" cells was generally limited to a total of 16; on occasion the preceding rules would not permit the completion of the third cell of an event because, for example, no target was available that had not appeared in the previous event or no target vehicle was available that was not in a 12 degree sector previously used in the event. In these cases, the cell was filled as a "No Target."

A set of three matrices was prepared by assigning each vehicle to a target position-generally assuring that a minimum of two vehicles were included in each of the 12 degree segments.

A program was written for an H-P 85 computer, which included all of the rules stated above, and simply required input of the target position for each target vehicle. Randomization of the target presentation sequence and target aspect were accomplished via the computer. A typical 15 event/45 cell matrix included 28 to 30 targets. A representative matrix is included in Table D-1.

Table D-1. Sample Smoke 5-B Target Matrix

EVENT	TARGET	POSITION	ASPECT	DEGREES AZIMUTH	CALL SIGN
1A	M113	E53	RO	51.1	Blue 3
1B	None				
1C	M113	D25	F	40.9	Blue 13
2A	None				
2B	M561	E51	RO	54.8	Blue 7
2C	M577	A29	LO	3.3	Blue 4
3A	M151	D39	RO	38.6	Blue 8
3B	M60	B27	F	16.2	Blue 1
3C	None				
4A	None				
4B	M35	A29	F	3.3	Blue 11
4C	M577	E47	LO	55.6	Blue 5
5A	M60	B27	LO	16.2	Blue 1
5B	M551	C31	F	25.1	Blue 12
5C	None				
6A	M35	D33	F	36.6	Blue 10
6B	M577	A29	F	3.3	Blue 4
6C	None				
7A	M561	E51	RO	54.8	Blue 7
7B	M60	B25	LO	17.6	Blue 2
7C	M35	A29	LO	3.3	Blue 11
8A	M113	E53	LO	51.1	Blue 3
8B	M60	B27	F	16.2	Blue 1
8C	M113	D25	F	40.9	Blue 13
9A	M577	E47	RO	55.6	Blue 5
9B	M35	A29	F	3.3	Blue 11
9C	M35	D33	F	36.6	Blue 10
10A	M151	D39	RO	38.6	Blue 8
10B	None				
10C	M151	C31	LO	25.1	Blue 12
11A	M656	B19	LO	14.3	Blue 9
11B	M577	A29	F	3.3	Blue 4
11C	M35	D33	RO	36.6	Blue 10
12A	M561	C51	LO	29.4	Blue 6
12B	None				
12C	None				

Table D-1. Sample Smoke 5-B Target Matrix (continued)

EVENT	TARGET	POSITION	ASPECT	DEGREES AZIMUTH	CALL SIGN
13A	None				
13B	None				
13C	None				
14A	M551	C31	RO	25.1	Blue 12
14B	None				
14C	M113	D25	LO	40.9	Blue 13
15A	M151	D39	LO	38.6	Blue 8
15B	None				
15C	None				

The following information was output with each matrix produced by the random matrix generator program for the H-P 85.

Target Distribution

Target Type	Position	Replicates	Percentage
M60	B27	3	6.67
M60	B25	1	2.22
M551	C31	3	6.67
M113	E53	2	4.44
M113	D25	3	6.67
M577	A29	3	6.67
M557	E47	2	4.44
M561	C37	1	2.22
M561	E51	2	4.44
M551	D39	3	6.67
M656	B19	1	2.22
M35	A29	3	6.67
M35	C31	3	6.67
No Target		15	

Total targets: 30
Total Number Targets: 15

Aspects:

F = Front
RO = Right Oblique
LO = Left Oblique

The target vehicles were repositioned after each three trials. This technique was used to allow bracketing of a smoke trial-designed to be the second trial of a sequence of three—with two clear air trials to permit comparison of the smoke trial with similar data from clear air trials using the same targets at the same ranges with reasonably similar environmental and target signature characteristics. In actual practice, however, obscurant trials were not always bracketed by similar clear air trials due to the unseasonable weather experienced during the obscurant phase of the experiment, which made it impractical to deploy obscurants.

A tally system was designed to maintain a running account of the number of replications of each target at each range. The minimum number of clear air trial replicates desired was 20 at each range from 1,500 meters to 5,500 meters for the duplicated vehicles and 15 replications at each range for the single targets, as listed in Section 4.0-Target Vehicles. Severe maintenance problems were encountered with the M60 tanks and, as a result, these vehicles were available for only about 20% of the trials. The desired number of replicates for the remaining vehicles during clear air trials was, by the conclusion of the experiment, over 90 percent completed, with most of the deficiencies at the nearest and longest ranges.

7.1 Target Deployment:

The original plan was to employ static targets almost exclusively and include a smaller number of moving targets, predominantly at longer ranges—4,500 meters or greater—in order to investigate the effect of motion on target detection capability. During the test range layout, prior to the start of the experiment, it became obvious that all of the target vehicles would be moving while in line of sight of the sensors when enroute from defilade to a target position. The average distance from defilade to a target position was about 50 meters. The approximate time that a moving vehicle was in line of sight to or from defilade was 20 seconds; the target vehicle would remain static at a target position for about 35 to 45 seconds. Thus, targets were displayed as moving a static for about an equal time. Data for detection of a moving target, as opposed to a static target, was collected by simply requiring the observer (response console operator) to input "moving" along with the detection response. (Note: In practice, this did not work out well. Several observers either did not input the "moving" response at all, or would only provide the information on occasion. Thus, the data analysis does not address moving versus static targets.) The observer response procedures are further detailed in Section 8.0.

Target vehicles were positioned statically in one of three aspects; Right Oblique, Front, or Left Oblique. This method was used because one would expect that an "attacking" vehicle would usually be sighted within the forward 120 degree aspect. The minimum target dimension is not affected by the aspects chosen, therefore aspect is not a data analysis consideration.

7.2 Test Methodology—Obscurant Trials:

The methodology for obscurant trials was, as previously stated, essentially the same as that used for the clear air trials. The methodology did, however, permit a period of clear air search—generally 2 to 5 minutes—to precede the dispersement of an obscurant. This method was employed to avoid cueing the sensor observers as to when an obscurant was scheduled in order to make more obvious any abrupt change in search strategy or search pattern.

8.0 OBSERVER TRAINING:

Observers were trained on each of three areas of target acquisition using thermal, television, and day sight sensors. The areas included in the instruction were: target signature interpretation, search, and sensor operation.

8.1 Target Signature Identification:

Observers were instructed using the following target signature training aids in the order listed:

a. Still photographs—visible spectrum

b. Slides—thermographs

c. Target Signature Handbook—cues for identification

d. Video tape—actual targets used in Smoke 5-B

e. Viewing real targets with the sensors used in the experiment (hands on training).

In addition to identification of vehicle signatures, the observers were taught to use the following definitions for the various levels of the target acquisition process.

a. Detection—the decision by the observer that an object perceived as foreign to the scene is of possible military significance.

b. Aim—once a potential target was found, the observer was instructed to center the target in the center of the sensor field of view or reticule and input the response "aim."

c. Classification—a decision by the observer that the target belonged to a particular class of target; in this experiment, wheeled versus tracked vehicles.

d. Recognition—the decision that the target was of a particular type. In the Smoke 5-B experiment, the target could be a truck, tank, or an APC.

e. Identification—this was the highest order response required by the observer during this experiment. Identification is defined as the decision that the target is a specific target, for example that the tank is an M60. (Note: Recognition was the highest order response for the wheeled vehicles.)

8.2 Search:

The search process was explained to the observers as a systematic investigation of a delineated terrain explored such that the probability of acquiring significant military targets is optimized. They were instructed to make target acquisition search in the wide field of view and to go to the narrow field of view (for those sensors so equipped) to achieve the recognition or identification levels. (Note: The observers were also instructed to input a field of view change response; i.e., "wide" or "narrow," however, as in the case of the "moving" target response, the input was not made consistently by all of the observers.) The observers were told that they could operate the sensors as they wished so long as their method was in keeping with the goal of optimizing target acquisition. In short, they were told that the search process should be organized, but not **how** it should be organized.

8.3 Sensor Operation:

Observers were instructed in the operation of the sensors, with special emphasis on the unique characteristics of each sensor. The characteristics that were stressed included:

AN/TAS-4; AN/TAS-2; and AN/VSG-2—focus adjustment, and the optimization of gain and level.

TOW Day Sight—focus

Silicon TV—focus, and brightness, and contrast setting for the TV display.

8.4 Observer Response Consoles:

Prior to the response console training phase, the observers were divided into two person teams. The teams remained the same throughout the test. Communication between the observer and the console operator were emphasized as critical to the collection of valid data. Console operators were instructed to verbally confirm each observer response in order to minimize data input errors. Several training trials using the same methodology as the data trials were conducted. Each observer team member was required to perform as an observer and as a console operator during the training and, later, during the test. (Note: The response consoles have been replaced by a voice recognition data input system. This system is programmed to a specific menu by the observer and interprets the voice pattern of the individual. This new system should virtually eliminate data input errors.)

9.0 METEOROLOGICAL SUMMARY:

On site meteorological data collection by the Atmospheric Sciences Laboratory (ASL) Meteorclogical Team attached to CNVEO in support of the Smoke 5-B field experiment was started on 6 October 1983, about 2 weeks prior to the first trials, in order to establish a preliminary data base as an indication of environmental trends or tendencies. Particular emphasis was placed on wind speed and wind direction measurements during daylight hours in an attempt to use these data to schedule obscurant trials.

A 10 meter high scaffold tower was erected approximately 50 meters southeast of the sensor platform. Meteorological measurement instruments installed on the tower were remoted by underground cable into the Smoke 5-B compound. The following environmental measurements were either recorded directly or calculated by and recorded on the Digi-3 Data Recorder.

Recorded Directly:

1. Wind direction—10 meters elevation
2. Wind speed—10 meters elevation
3. Ambient temperature at 2 meters and 10 meters
4. Wet bulb temperature at 2 meters
5. Atmospheric pressure at 2 meters
6. Solar radiation
7. Terrestrial radiation
8. Soil temperature

Calculated Measurements:

1. 3 hour average of wind speed and direction
2. Temperature differences between 2 meters and 10 meters*
3. Minimum and maximum temperature*
4. Relative humidity*
5. Net radiation*

* Calculated at the data recording frequency.

The frequency that the meteorological measurements were recorded varied with the test schedule as follows:

Clear Air Trials:

All measurements and calculations were recorded at 20 minute intervals except during periods that indicated dynamic conditions that may affect sensor performance or target signatures. For example, precipitation or winds in excess of 20 miles/hour. When these conditions occurred, the measurements were recorded at 5 minute intervals.

Obscurant Trials:

Measurements were recorded at 10 second intervals commencing 30 minutes prior to the scheduled release of an obscurant (see note) and at 1 minute intervals until the obscurant was disbursed or until the end of the trial. (Note: The 10 second interval was needed to compute the Pasquill Stability Category that was used as a decision tool for obscurant dispersement. Only the wind speed and wind direction were required for Pasquill Categorization; however, since the measurements were automatically recorded, all parameters were recorded at the same frequency.)

Non-Test Periods:

During periods of no testing, including nights, weekends, and holidays, the meteorological data was recorded at 1 hour intervals.

Libby Army Airfield Meteorological Data:

In addition to the meteorological data recorded at the Smoke 5-B test site, the ASL meteorological team attached to Fort Huachuca made and provided the following measurements and observations at a site near Libby Army Airfield, located about 8km southeast of the Smoke 5-B site.

1. Temperature
2. Relative humidity
3. Wind speed
4. Wind direction
5. Precipitation
6. Visibility
7. Cloud cover
8. Sun angle (azimuth and elevation)
9. Sun rise and sun set (from charts)

These data were recorded at 15 minute intervals from between 0600 and 1800 on scheduled Smoke 5-B test days. The remote measurements and observations served two purposes: (1) to determine that the obscurants did not create a safety hazard to aviation activities, and (2) to provide an indication of the variability or the stability of meteorological conditions in the area adjacent to the Smoke 5-B test site. Since there is a reasonable probability that similar experiments will be conducted by CNVEO and PM-Smoke, the ASL meteorological team has set up an automatic measurement system to record temperature, relative humidity, and wind speed/direction continuously 24 hours a day at the Smoke 5-B compound. These data will assist in determining the differences, if they exist, between conditions at the permanent meteorological recording site at Libby Army Airfield—which is the only site for historical data available from Fort Huachuca—and the test site.

10.0 MEASUREMENT EQUIPMENT/TECHNIQUES:

The major equipments used to determine observer behavior were:

1. Data General Automatic Field Data System (AUTOFEDS) Computer
2. Shaft Encoded Tripod Heads
3. Multi-Target Tracker
4. Observer Response Consoles

(1) The AUTOFEDS computer was used to input, store, sort, collate, and output the observer response data, search pattern data, and applicable environmental and target signature data. Target signature and environmental data were input "off line," after a trial was completed. The remaining data were input in real time. All data input to AUTOFEDS was IRIG-B time tagged. Software compatible with the experimental methodology and data input and on site data output requirements were prepared prior to and during the test. (Note: The on site software was adequate to maintain a daily progress update; however, the software required for in-depth evaluation and analysis of the results was not written until the test was completed.)

(2) Each sensor was installed on a shaft encoder equipped tripod to permit the recording of search pattern data and determine the sensor azimuth simultaneous with observer responses. The sensor azimuth was recorded at a frequency of four times per second. The accuracy of the encoders was within 0.1 degree.

(3) The Multi-Target Tracker was used to determine, and input to the computer, when line of sight to a target was established or broken. The Multi-Target Tracker was used to track and update azimuth position and range of each of up to 15 vehicles once every 1.5 seconds, whether static or moving. The tracker is accurate to within 0.1 degrees in azimuth. The range to target accuracy is 5 meters or less.

(4) The observer response consoles permit input of target detection and interrogation data, sensor field of view changes, and specific responses including "aim" (centering of a target in the sensor image) and "search" (resumption of search after a target interrogation has been completed). An "error" response is included to permit an observer to correct a response, as is a "moving" response used when a target was seen to be moving at the time it was detected. Communication between the observer and the response console operator was accomplished via microphone equipped headsets.

10.1 Measurement Techniques:

The performance measurement equipment enabled the input of the data necessary to not only indicate when an observer acquired a target, for example, but to verify that a specific target was acquired by comparing the sensor azimuth, as determined by the shaft encoder on the tripod, to the known surveyed target azimuth and the target tracker azimuth input. Thus, a "triple check" technique was used to verify the observer response and, as a result, permit the accurate determination of false alarm rate as well as man/sensor target acquisition performance. The measurement equipment also permitted a highly accurate determination of observer search pattern, variance of search pattern during obscurant events, and search scan rate.

10.2 Environmental Measurement Equipment/Techniques:

Environmental measurements include atmospheric transmission measurements, obscurant cloud formation measurements, and target signature measurements.

10.3 Atmospheric Transmission:

Atmospheric transmission data was recorded in the visible (0.4 to 0.7µm); silicon (1.06µm); and the 3 to 5µm and 8 to 12µ infrared bands. Several transmissometer equipments were used. These included:

(1) Multispectral/Multi-source Transmissometer (Dutch-Danish "Du-Da" System)

The "Du-Da" system was used to measure atmospheric transmission on a 500 meter path length through the obscurant cloud. Multispectral (3 to 5µm and 8 to 12µm) sources were set up at 5 degree intervals across the search fan. The instrument is capable of measuring the transmission to each source in each infrared spectral band about once every 0.5 second. Short path clear air measurements were made prior to the deployment of an obscurant. It is worth noting that the sources for this transmissometer were baffled so they could not be readily detected by any of the sensors. This point is addressed because conventional transmissometer sources, when placed in the line of sight of electro-optical sensors, tend to saturate the sensor electronics and, consequently, significantly degrade the sensor imagery. The "Du-Da" was also used to measure obscurant cloud radiance in the two infrared spectral bands. The system has the additional capability to measure discrete infrared transmission and radiance. It can be used as an infrared line scanner, as well, to measure target signatures.

(2) Long Range Variable Infrared (LOVIR) Multispectral Transmissometer (ASL)

The LOVIR transmissometer was used to measure clear air and obscurant cloud atmospheric transmission over two paths (500 meters). The multi-color sources were located outside of the active sensor search fan. Measurements were made in the visible, silicon, and the two infrared bands.

(3) Long Path Multispectral Transmissometer (SMART System)

This transmissometer from ASL was used to measure clear air and obscurant cloud transmission over 1,000 meter path. The source was set up outside the active sensor search fan and, consequently, had a slight angular path through the obscurants. The SMART System was not part of the Smoke 5-B measurement requirements; although the data will be available for analysis, if needed.

Each transmissometer system has the capability to output a continuous atmospheric transmission history. These data are being used to aid in the obscurant cloud quantification analysis by PM-Smoke and were used by CNVEO in the analysis of sensor performance and search performance in the obscured environment.

10.4 Obscurant Growth Measurements:

The obscurant cloud propagation measurements were made using the ASL Multispectral Digital Imaging System (MIDIS). Multispectral imagery was recorded from two surveyed locations—two axis—in the 3 to 5μm, 8 to 12μm, and visible spectrums. Algorithms developed by ASL are used to reduce and analyze the MIDIS imagery and, when correlated to the meteorological and environmental data, result in an accurate two axis propagation pattern or "map" of the obscurant cloud growth for each obscurant trial. The MIDIS data are used by PM-Smoke to aid in obscurant quantification.

10.5 Target Signature Measurements:

Target signatures, or target-to-background contrast were measured for the visible, silicon (0.73 to 1.0μm), and the 8 to 12μm spectral regions. The equipment to measure 3 to 5μm target signatures was not available. The instrumentation required to perform the target signature measurements was as follows:

Model DL-1 Calibrated Infrared Imager: 8 to 12μm band

Telephotometer, Extended Red: Visible and Silicon bands

Target signatures were determined for each target at least once during each trial for the 8 to 12 μm band, and for most targets in the visible and silicon bands. (Note: There were a few trials when either the silicon or visible target signature, but not both, was measured.) The reduction of target signatures data was conducted on a continuous basis and input and collated, via the AUTOFEDS, to the relevant sensor performance data.

11.0 CONCLUSIONS:

The Smoke 5-B field test was, in most aspects, very successful. The correlation of sensor performance and search performance data with the extensive meteorological and environmental data base has permitted, for the first time, a comparison of electro-optical sensors in a constant stimulus search environment for clear air and obscured conditions. Further, the Smoke 5-B experiment was the initial attempt to quantify the effects of the deployment of substantial amounts of obscurant material over a considerable period of time on the performance of electro-optical sensors. The preliminary data deduction and analysis indicate that the goals set forth in the test design have been met or exceeded. During and after the test, however, it became obvious that some areas of the experiment could be improved upon and/or extended to provide additional information of interest. These include:

(1) The data input software should be designed to format data for each system. Compatible output software would then permit printouts and/or graphic data within a few hours, rather than several days, after each trial. (Hardware limitations were in part responsible for these limitations during the experiment. Procurement of compatible hardware has been accomplished by CNVEO; the required software has been written as well and was used for the analysis in the final report.)

(2) Future similar field tests should limit the obscurant types to those of greater interest and/or military potential while insuring that an adequate number of trials are conducted, using each obscurant, to result in a statistically significant data base.

(3) Future tests of this sort should include night clear air trials and, if logistically feasible, night obscurant trials.

(4) The technique used to input observer response data should be improved upon, if possible. The response consoles are prone to time delays and errors that, at the least, increase the difficulty of analyzing these data. (Note: The response consoles have been replaced by the voice response system, as previously noted.)

(5) The combination of the AUTOFEDS computer and the multi-target tracker will allow target vehicles essentially "free play," if desired, during future tests. This would permit an even greater degree of realism while not compromising data collection or ground truthing.

(6) The multi-target tracker has proved to be a very useful technology. An added benefit is that, in contrast to other target tracking methodologies, such as the MILES system, it can be used successfully in obscured environments.

APPENDIX E
METEOROLOGICAL DATA SUMMARIES

On-site meteorological measurements were started about 2 weeks prior to the first data trials in order to establish a preliminary data base as an indication of weather trends and tendencies. The meteorological measurement instrumentation was installed on a 10 meter high tower adjacent to the test site. Measured and calculated parameters were recorded at 20-minute intervals throughout each test period. The meteorological data was recorded at 1-hour intervals during periods of no testing; i.e., nights, weekends, and holidays.

Meteorological measurements and observations were also made at Libby Army Airfield, about 5km southeast of the Smoke 5-B test site. The primary purpose of the Libby Field measurements was to determine if significant differences in meteorological conditions existed between the two relatively close sites.

The data presented in this appendix are in graphic format and include:

Visibility (Km)
Temperature (Degrees Celsius)
Relative Humidity (%)
Solar Radiation (Langleys)
Terrestrial Radiation (Langleys)
Soil Temperature (Degrees Celsius)
Sun Elevation (Degrees Above the Horizon)
Wind Speed (Miles/Hour)
Wind Direction
Atmospheric Pressure (Milibars)

Table E-1 includes the date, trial number, and start time for each trial, thus the existing meteorological conditions during each trial can be determined. (Each trial lasted approximately 20 minutes.)

The meteorological measurement techniques are presented in more detail in Appendix D, Section 9.0, Meteorological Summary.

Table E-1. Meteorological Data Summaries; Trial Numbers, Dates, Start Times

1983 DATE	TRIAL NUMBER	START TIME	1983 DATE	TRIAL NUMBER	START TIME
10-22	114	0920	11-02	156	0935
	115	1153		157	1013
	116	1434		160	1251
				161	1331
10-24	117	1425		162	1409
	118	1509		163	1445
				164	1522
10-26	119	0930		165	1603
	120	1059			
	121	1141	11-03	166	1031
	122	1300		170	1549
	123	1344		171	1402
	124	1426		172	1438
	125	1551		173	1515
10-27	126	1116	11-04	174	1014
	127	1155		175	1053
	128	1305		176	1131
	129	1505		177	1210
				178	1310
10-28	131	0849		179	1352
	132	1016		180	1436
	133	1057		181	1517
	134	1316			
	135	1407	11-05	182	0929
	136	1445		183	1012
				184	1051
10-31	138	0903		185	1128
	139	0939		186	1205
	140	1015		187	1243
	141	1050		188	1320
	142	1200		189	1353
	143	1233		190	1435
	144	1320		191	1511
11-01	148	1013	11-07	192	0827
	149	1048		193	0908
	146	1129		194	0951
	150	1233		195	1046
	151	1308		196	1141
	152	1348		197	1218
	153	1431		198	1302
	154	1525		199	1340
	155	1605		201	1505

Table E-1. Meteorological Data Summaries; Trial Numbers, Dates, Start Times (continued)

1983 DATE	TRIAL NUMBER	START TIME
11-7	202	1536
	203	1605
11-08	204	0852
	205	0929
	206	1006
	207	1039
	208	1258
	209	1344
	210	1425
	211	1500
11-09	212	0840
	213	0915
	214	0955
	215	1035
	216	1143
	217	1233
	218	1315
	219	1403
	220	1458
	221	1539

1983 DATE	TRIAL NUMBER	START TIME
11-10	222	0854
	223	0937
	224	1019
	225	1104
	226	1209
	227	1249
	230	1505
	231	1535
11-11	232	0850
	233	0931
	234	1010
	235	1050
	236	1149
	237	1232
	238	1322
11-12	240	0910
	241	0949
	242	1029
	243	1102
	244	1150
	245	1229

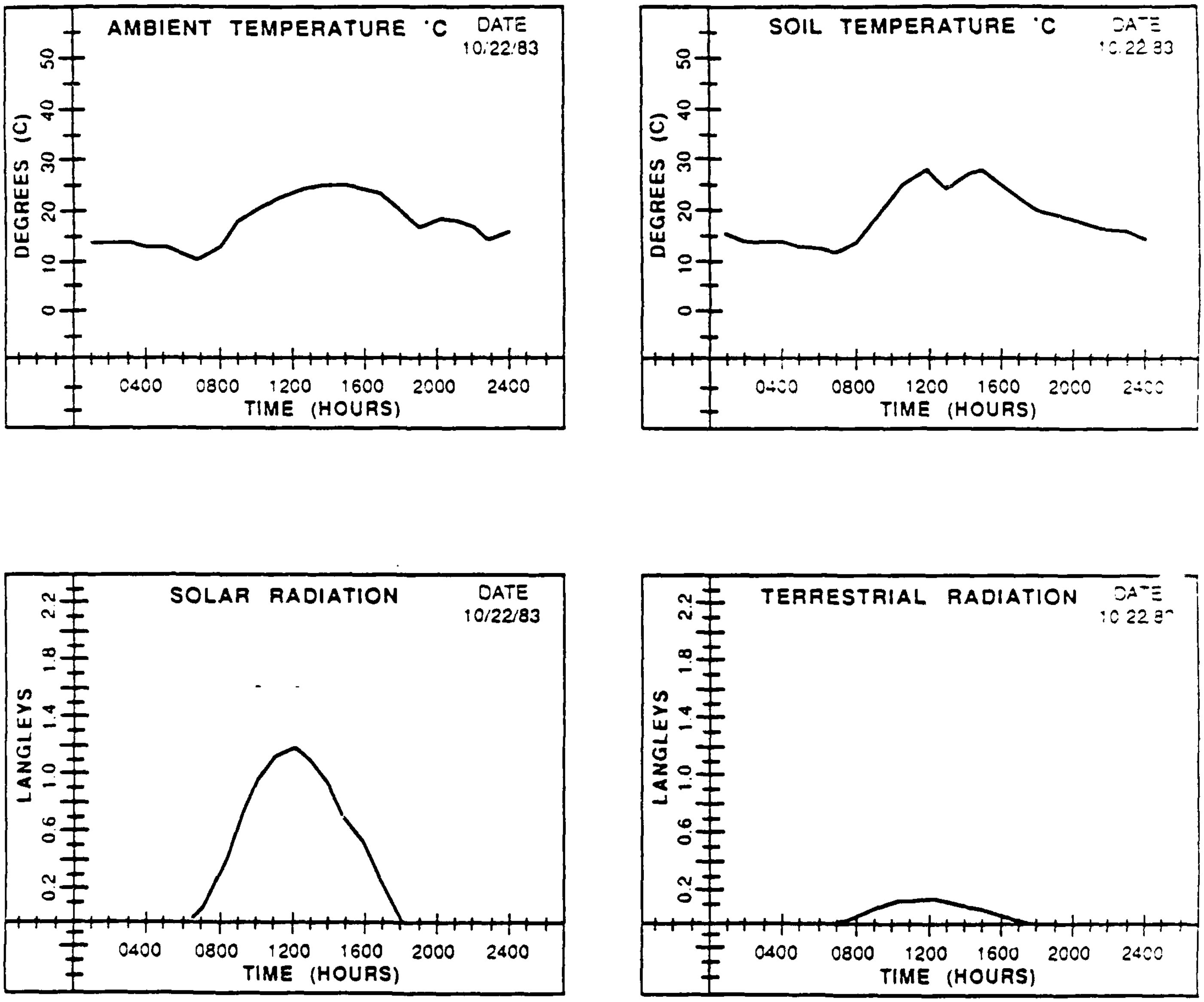
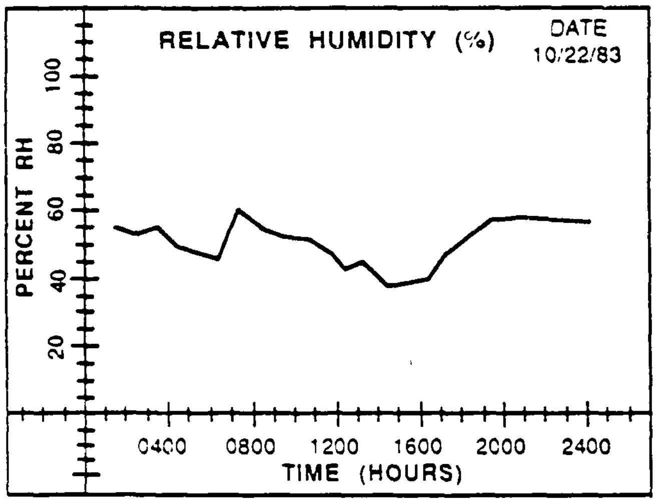
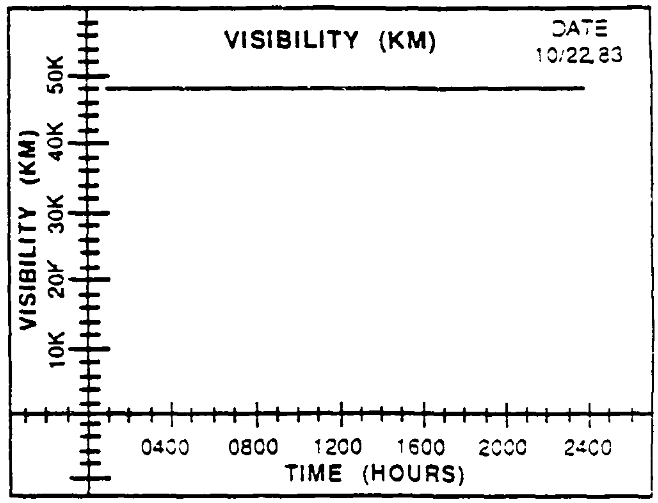
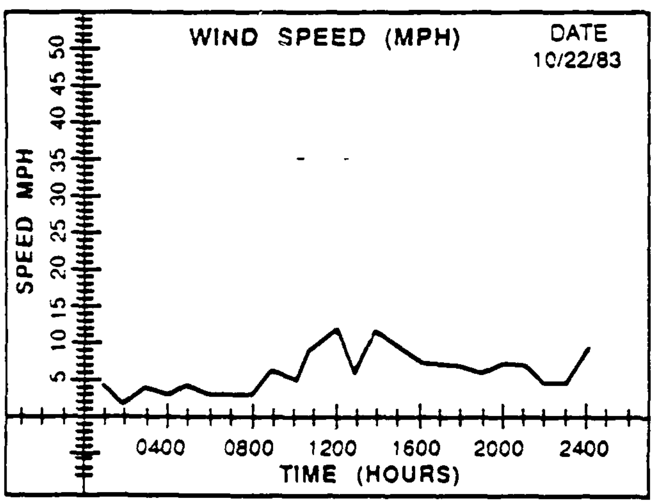

AMBIENT TEMPERATURE °C
DATE
10/22/83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOIL TEMPERATURE °C
DEGREES (C)
0 10 20 30 40 50
0800 1200 1600 2000
TIME (HOURS)
SOLAR RADIATION
DATE
10/22/83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)
TERRESTRIAL RADIATION
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000
TIME (HOURS)

Figure E-1







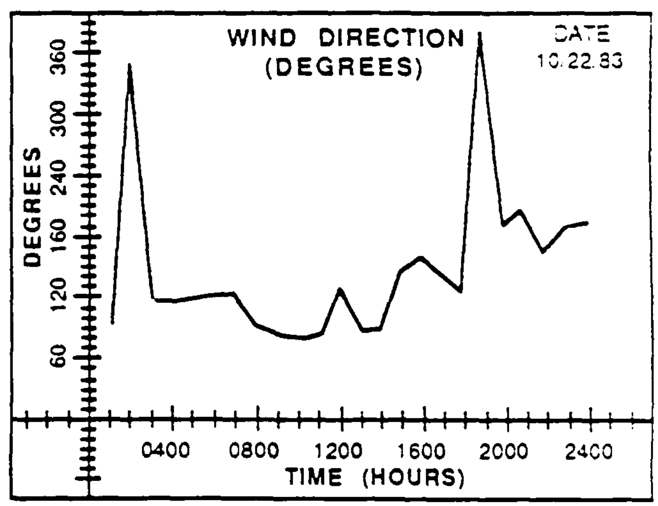


Figure E-1 (continued)

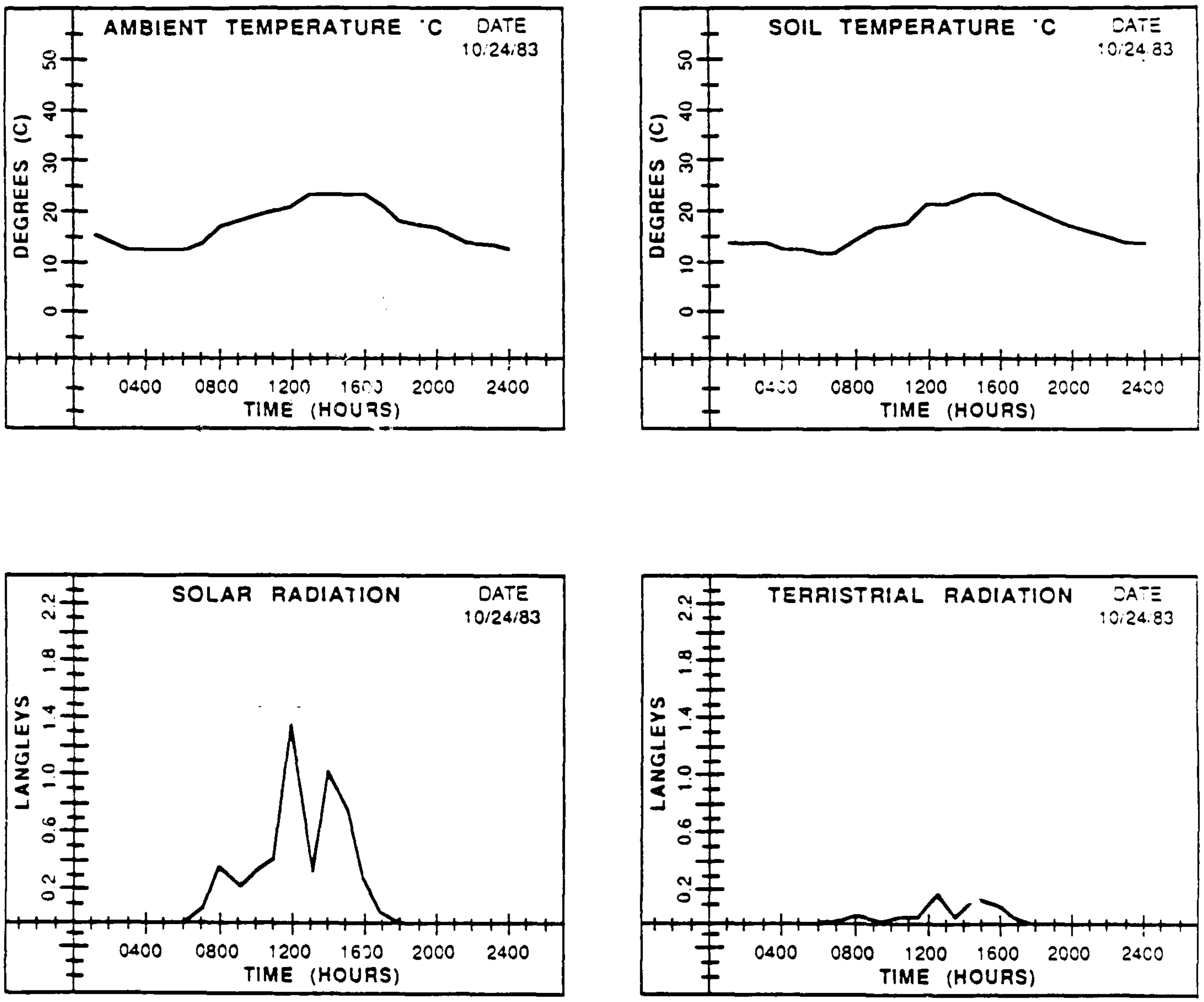

AMBIENT TEMPERATURE °C
DATE
10/24/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE
10/24/83
DEGREES (C)
0
10
20
30
40
50
0800
1200
1600
2000
TIME (HOURS)
SOLAR RADIATION
DATE
10/24/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
2000
2400
TIME (HOURS)
TERRISTRIAL RADIATION
DATE
10/24/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
TIME (HOURS)

Figure E-2

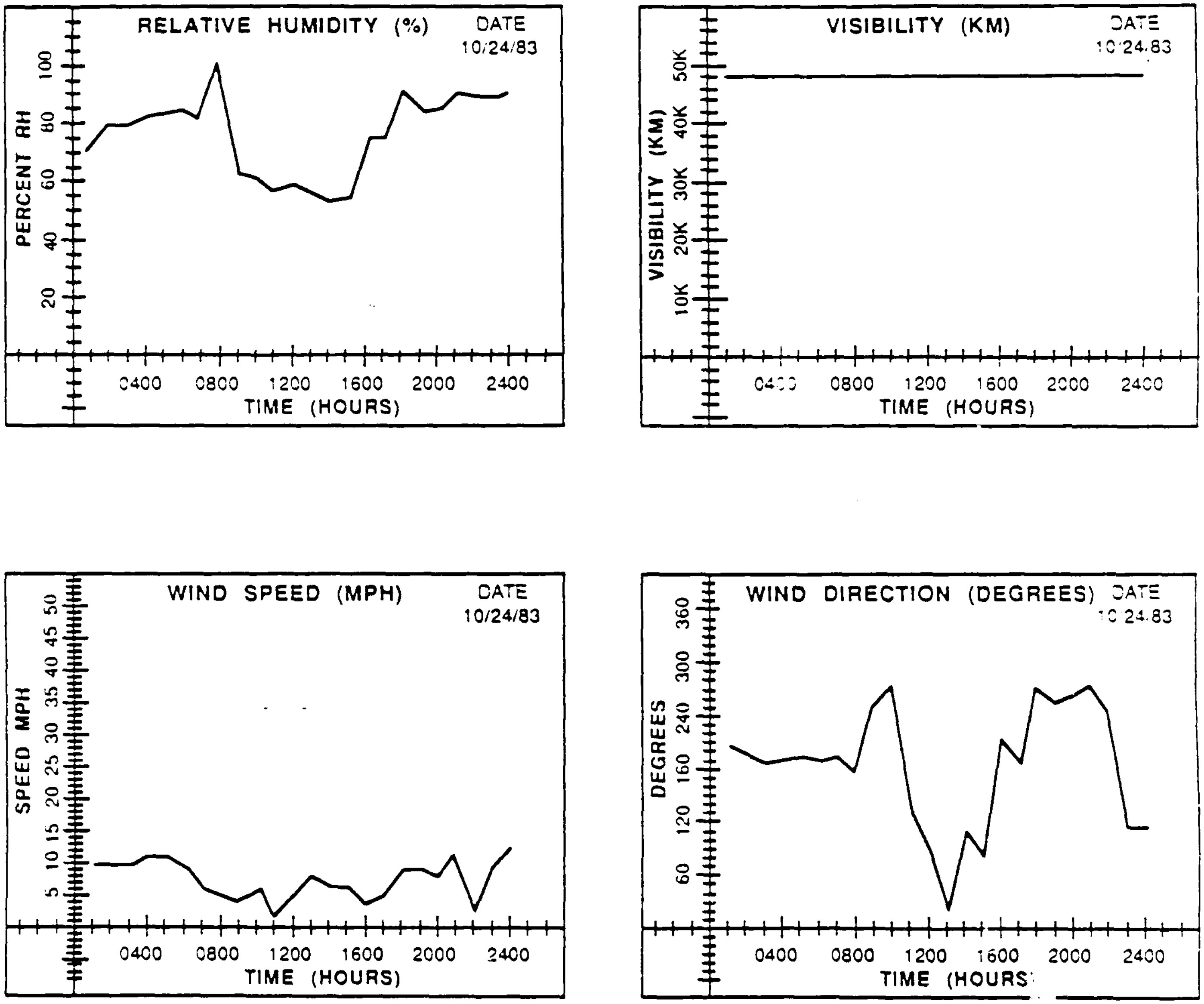


Figure E-2 (continued)

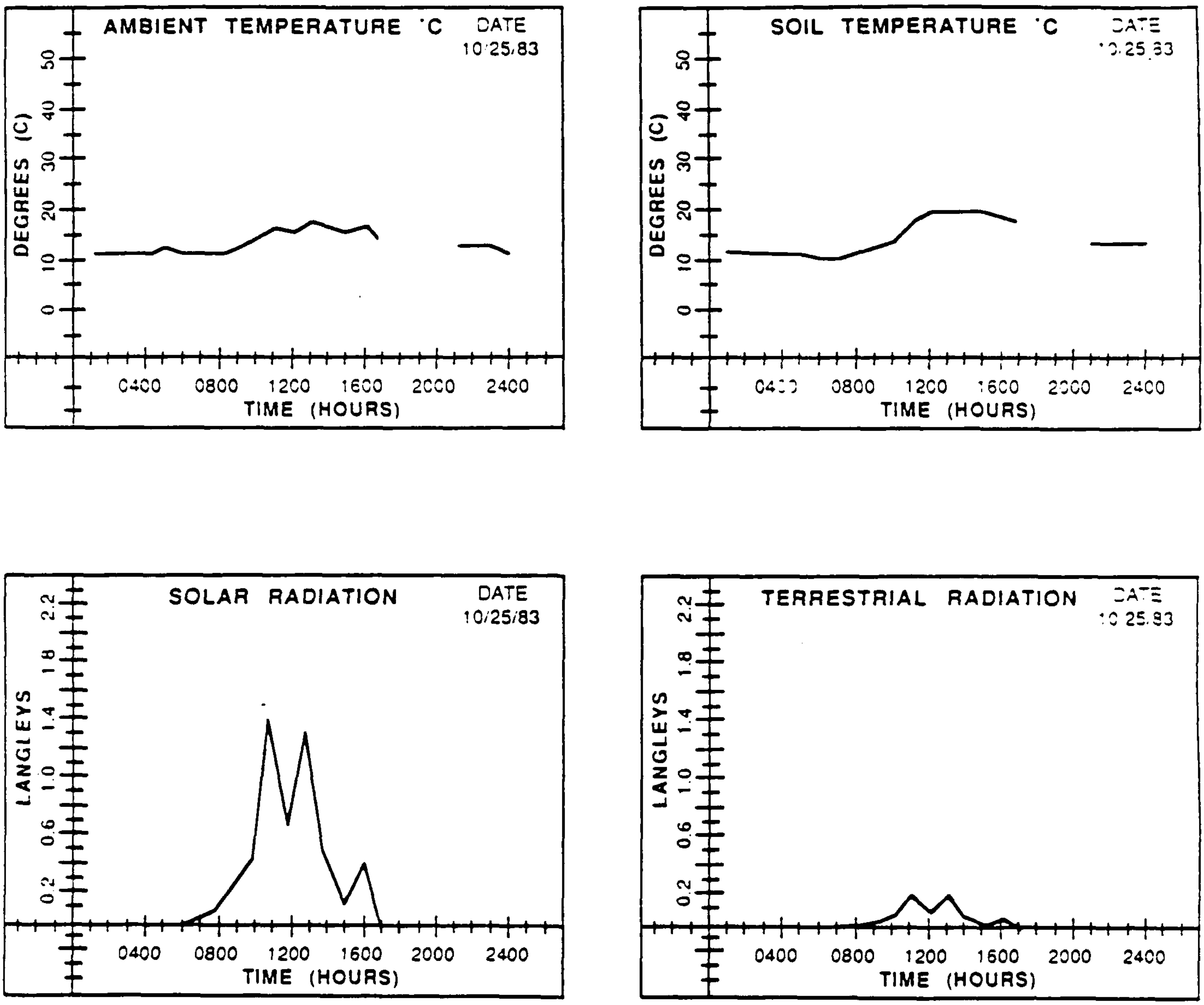

AMBIENT TEMPERATURE °C
DATE 10/25/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DEGREES (C)
TIME (HOURS)
SOLAR RADIATION
DATE 10/25/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
TIME (HOURS)
TERRESTRIAL RADIATION
LANGLEYS
TIME (HOURS)

Figure E-3

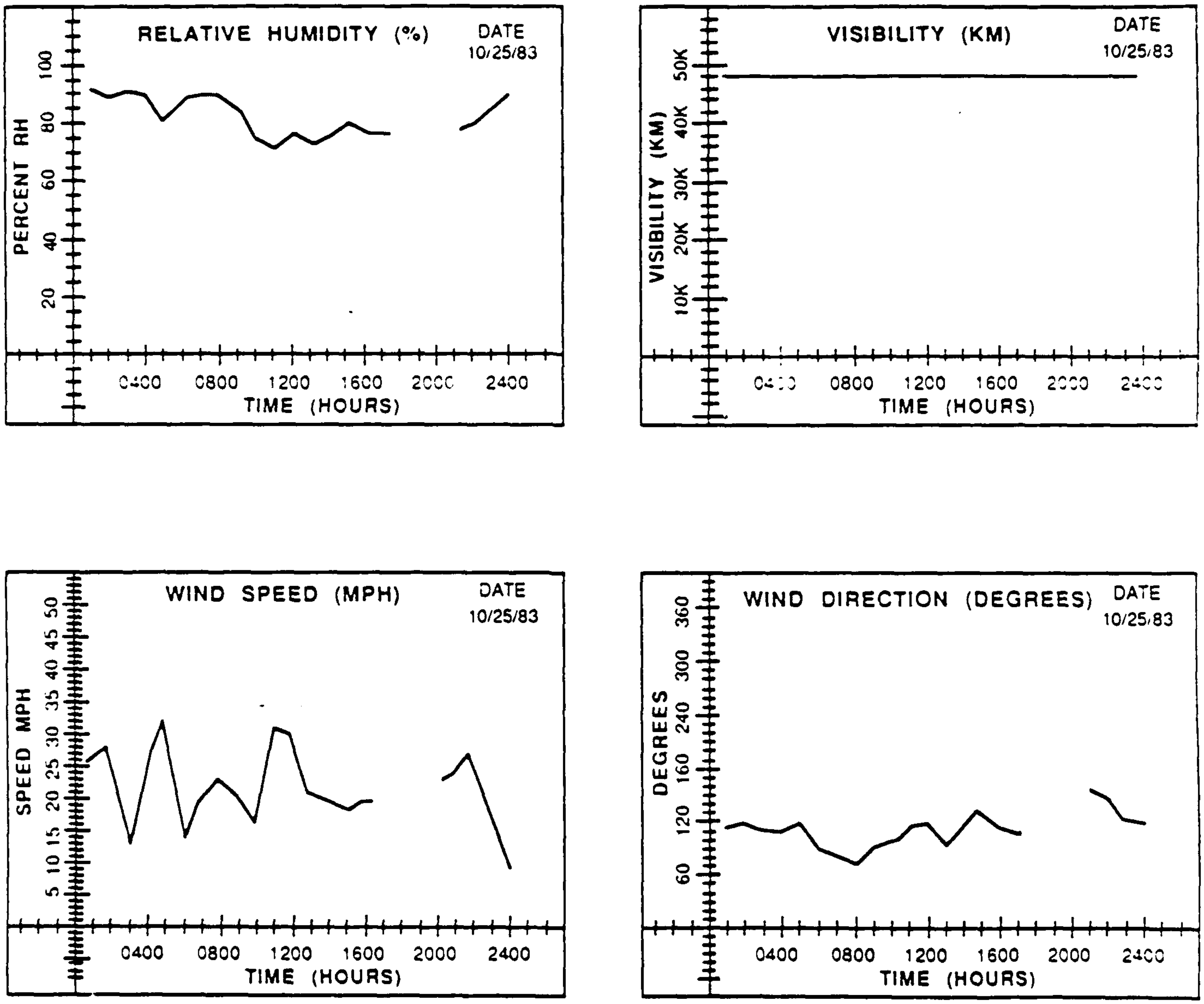


Figure E-3 (continued)

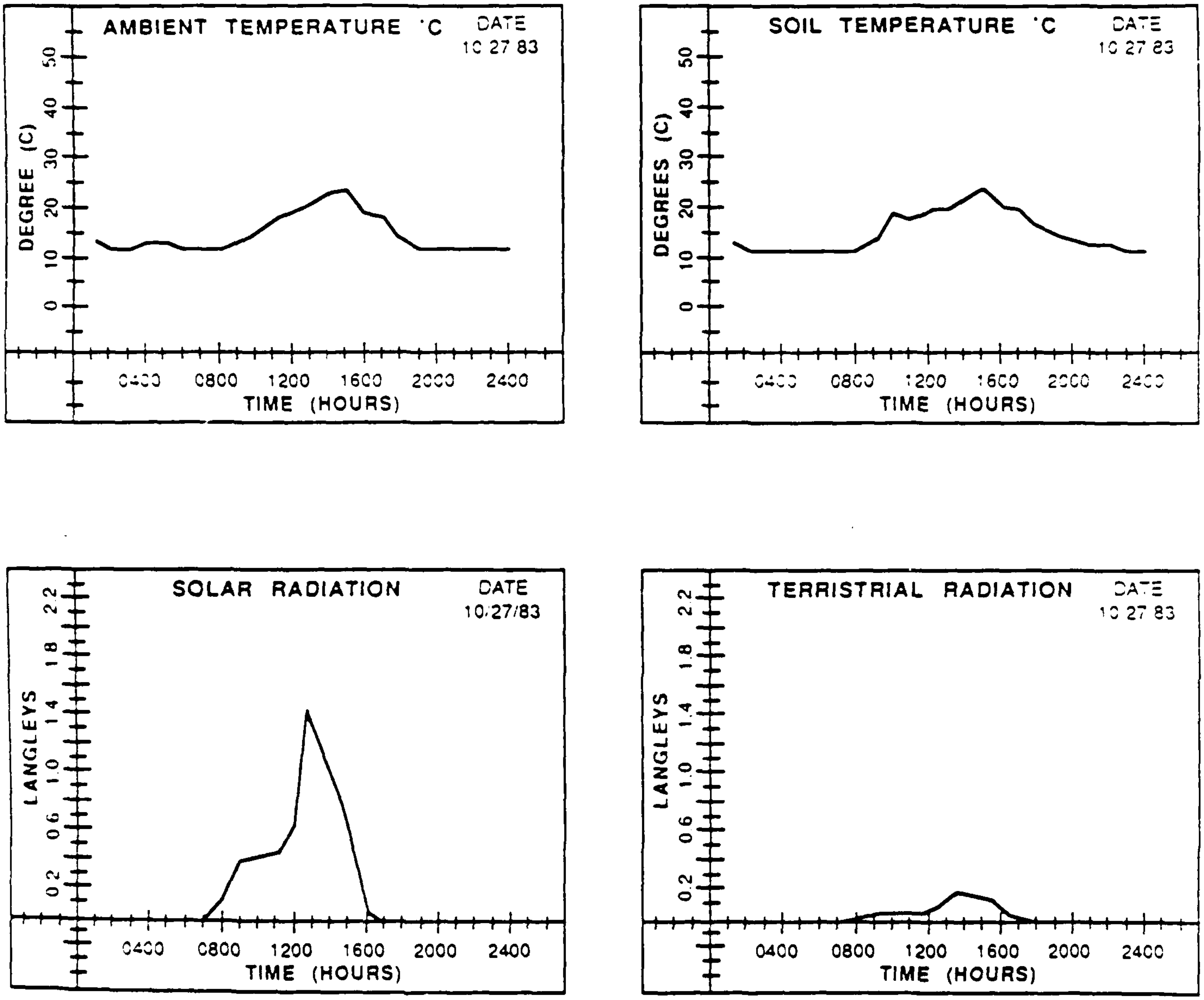

AMBIENT TEMPERATURE °C
DATE
10 27 83
DEGREE (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE
10 27 83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOLAR RADIATION
DATE
10/27/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)
TERRISTRIAL RADIATION
DATE
10 27 83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)

Figure E-4

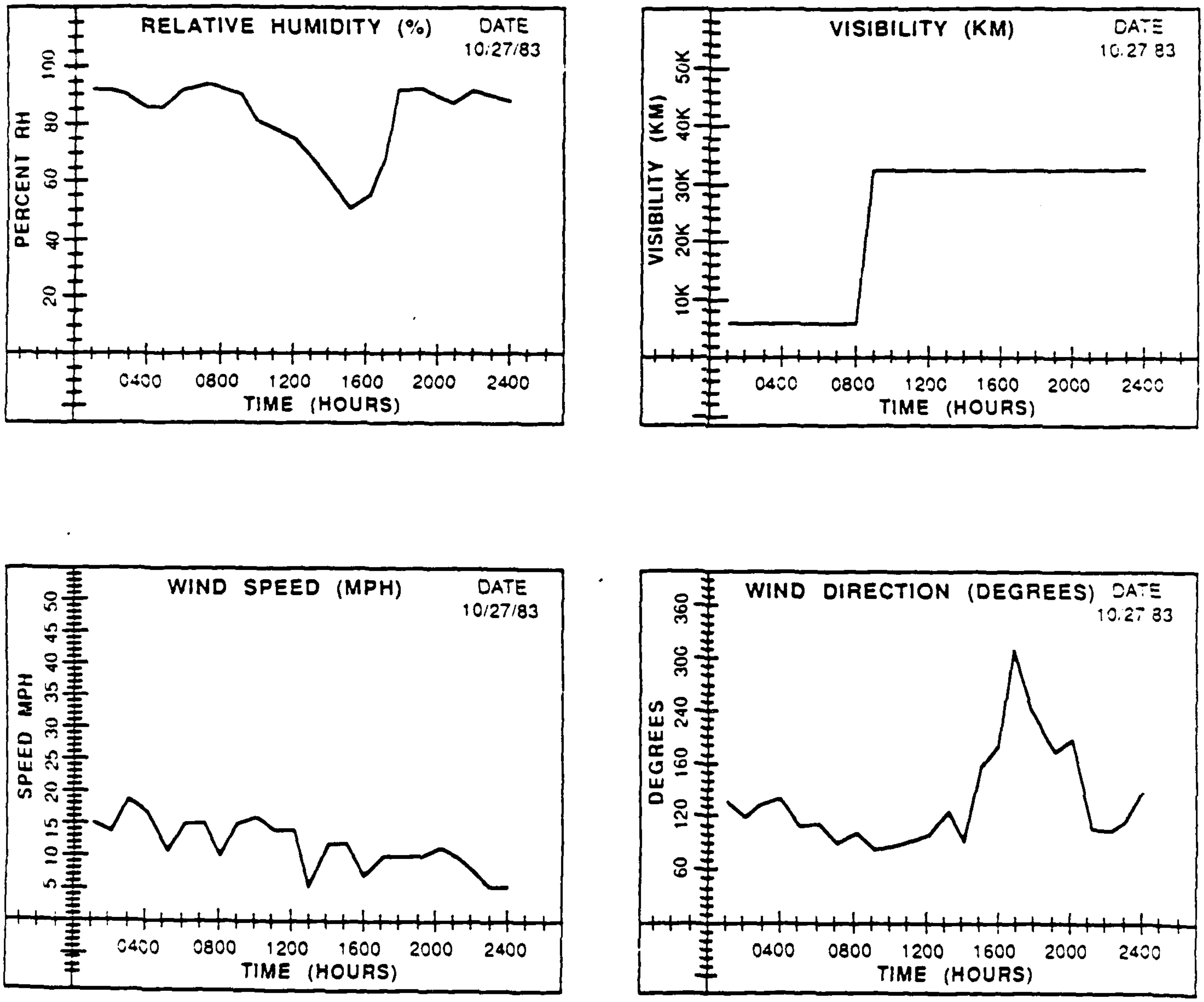


Figure E-4 (continued)

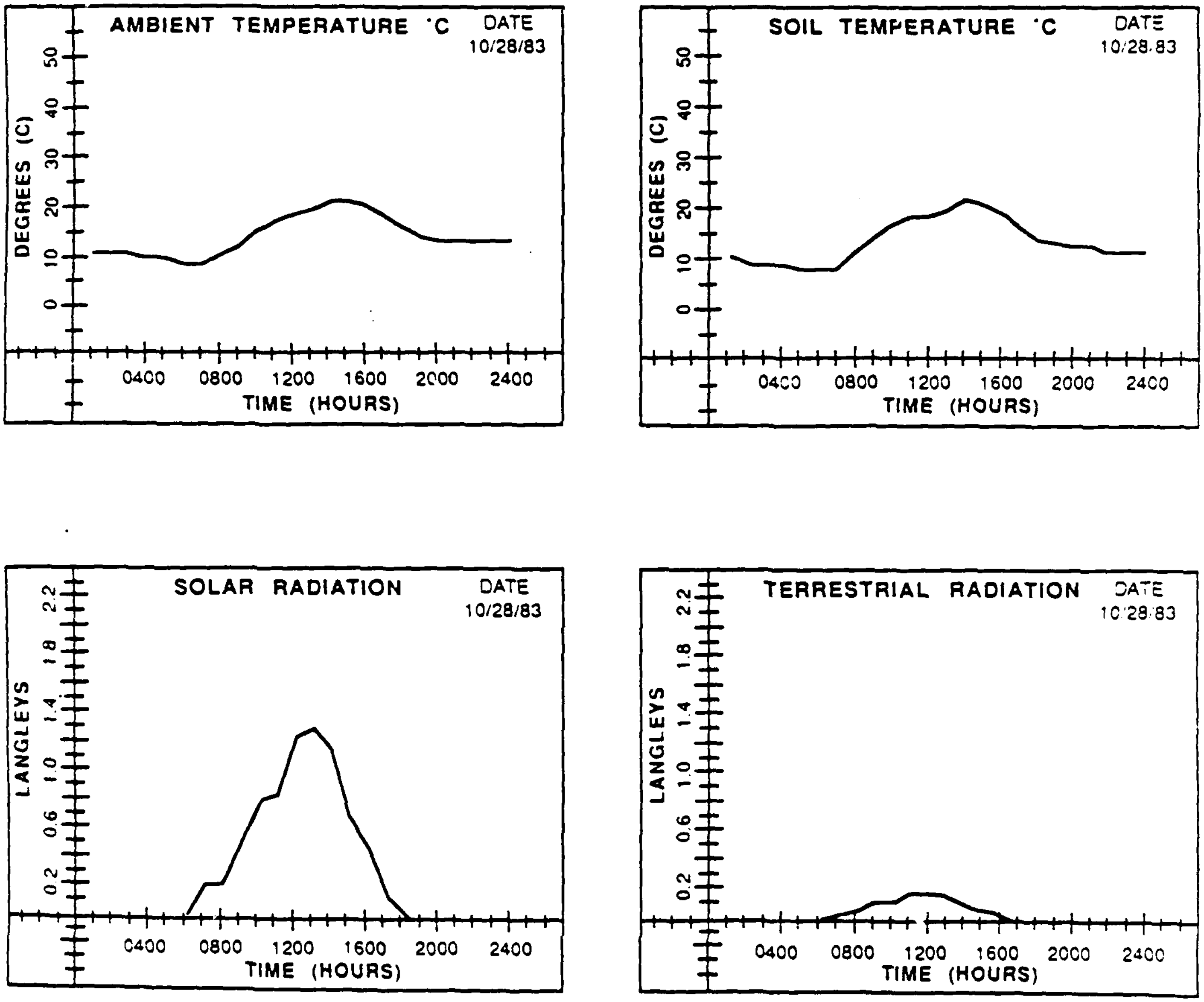

AMBIENT TEMPERATURE °C
DATE 10/28/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE 10/28/83
DEGREES (C)
SOLAR RADIATION
DATE 10/28/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
TIME (HOURS)
TERRESTRIAL RADIATION
DATE 10/28/83
LANGLEYS
TIME (HOURS)

Figure E-5

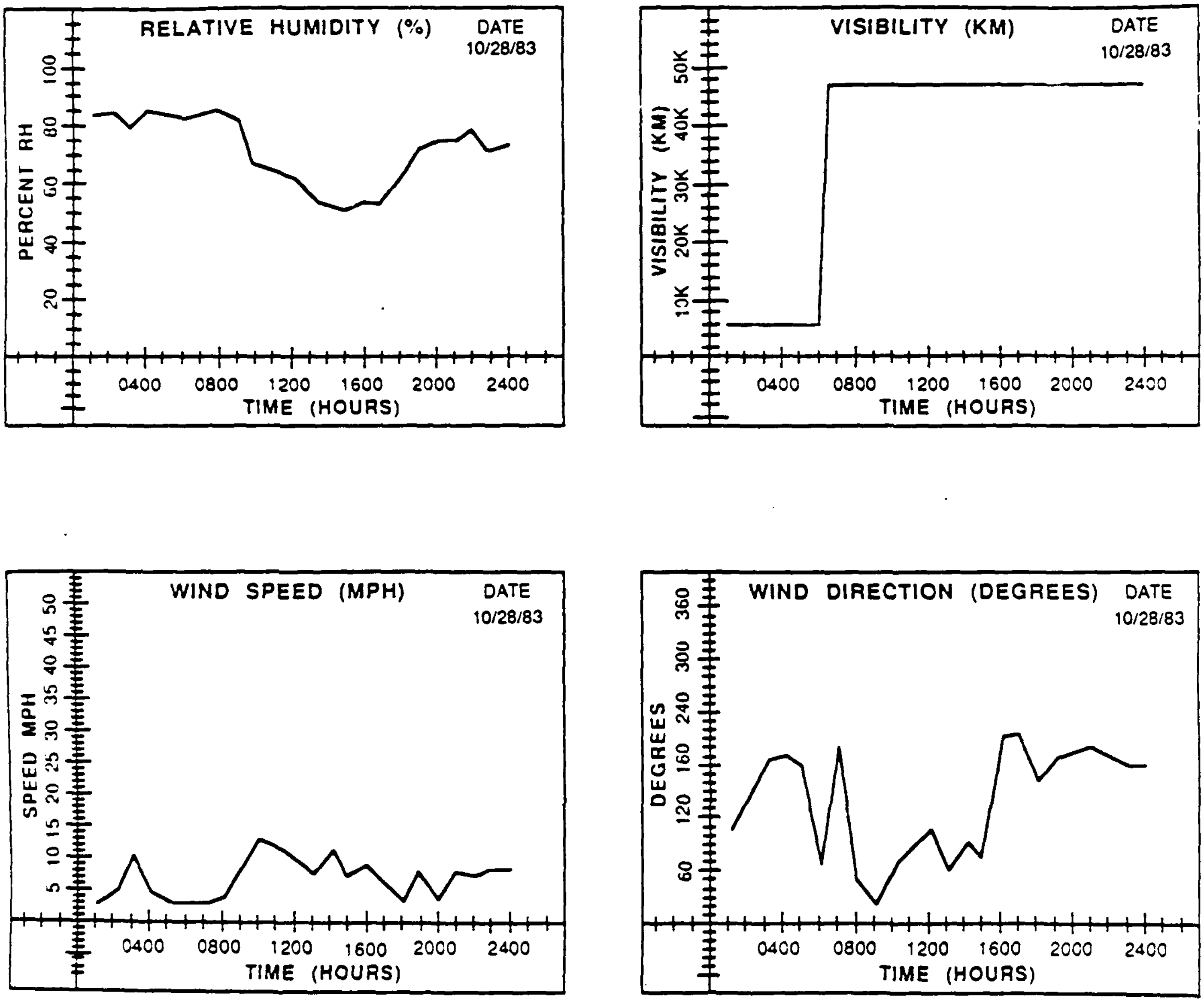


Figure E-5 (continued)

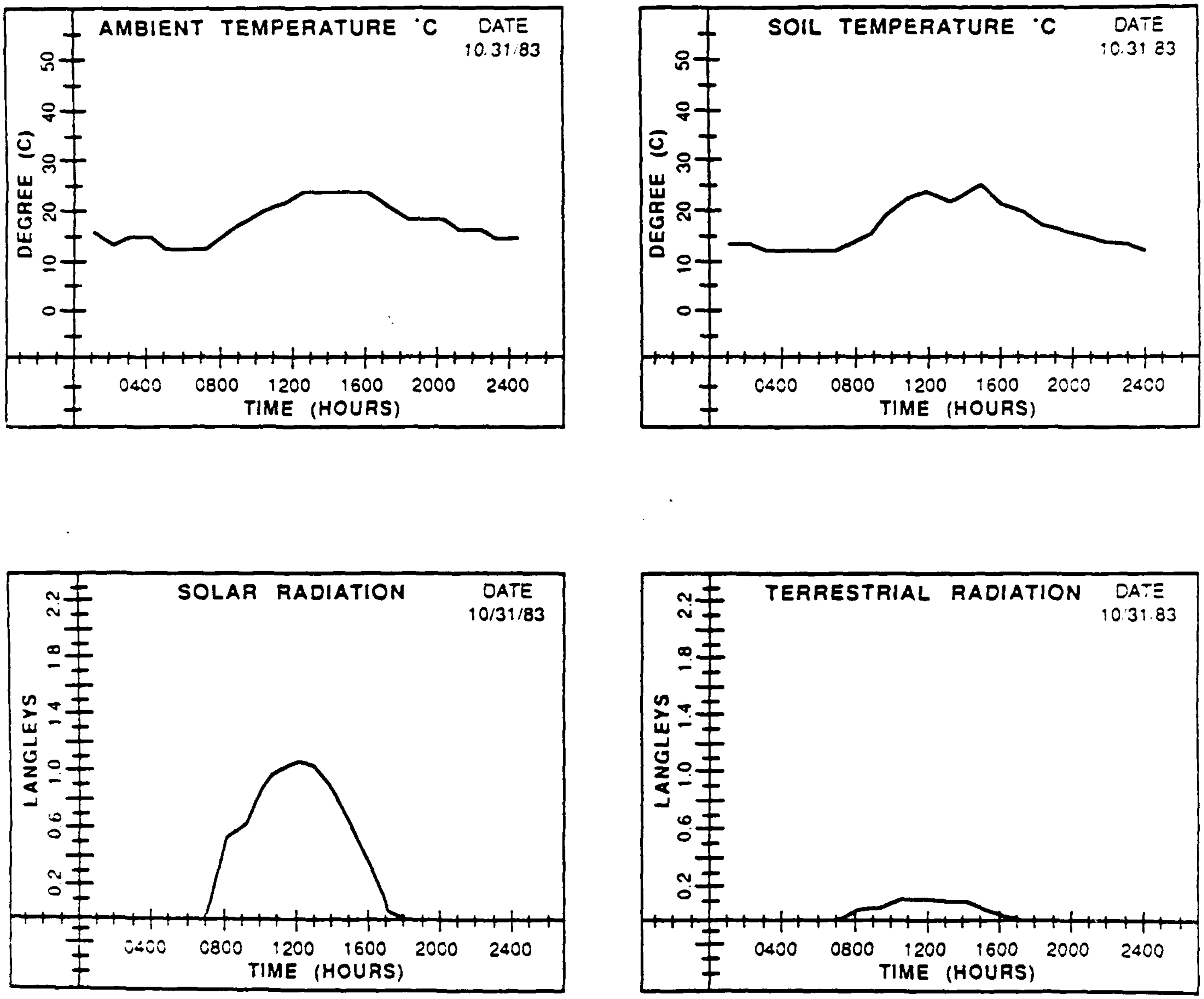

AMBIENT TEMPERATURE °C
DATE 10/31/83
DEGREE (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE 10/31/83
DEGREE (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOLAR RADIATION
DATE 10/31/83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)
TERRESTRIAL RADIATION
DATE 10/31/83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)

Figure E-6

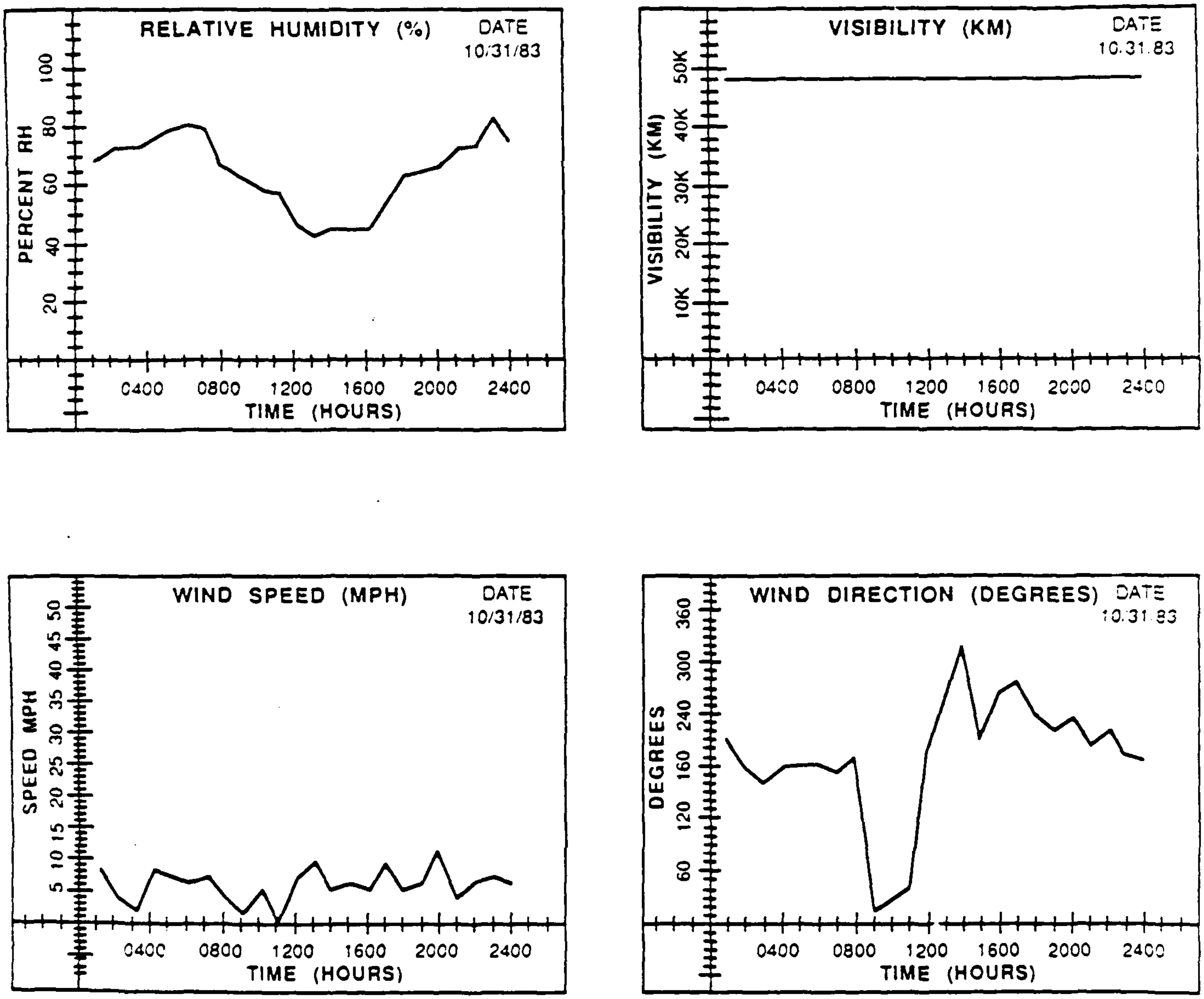


Figure E-6 (continued)

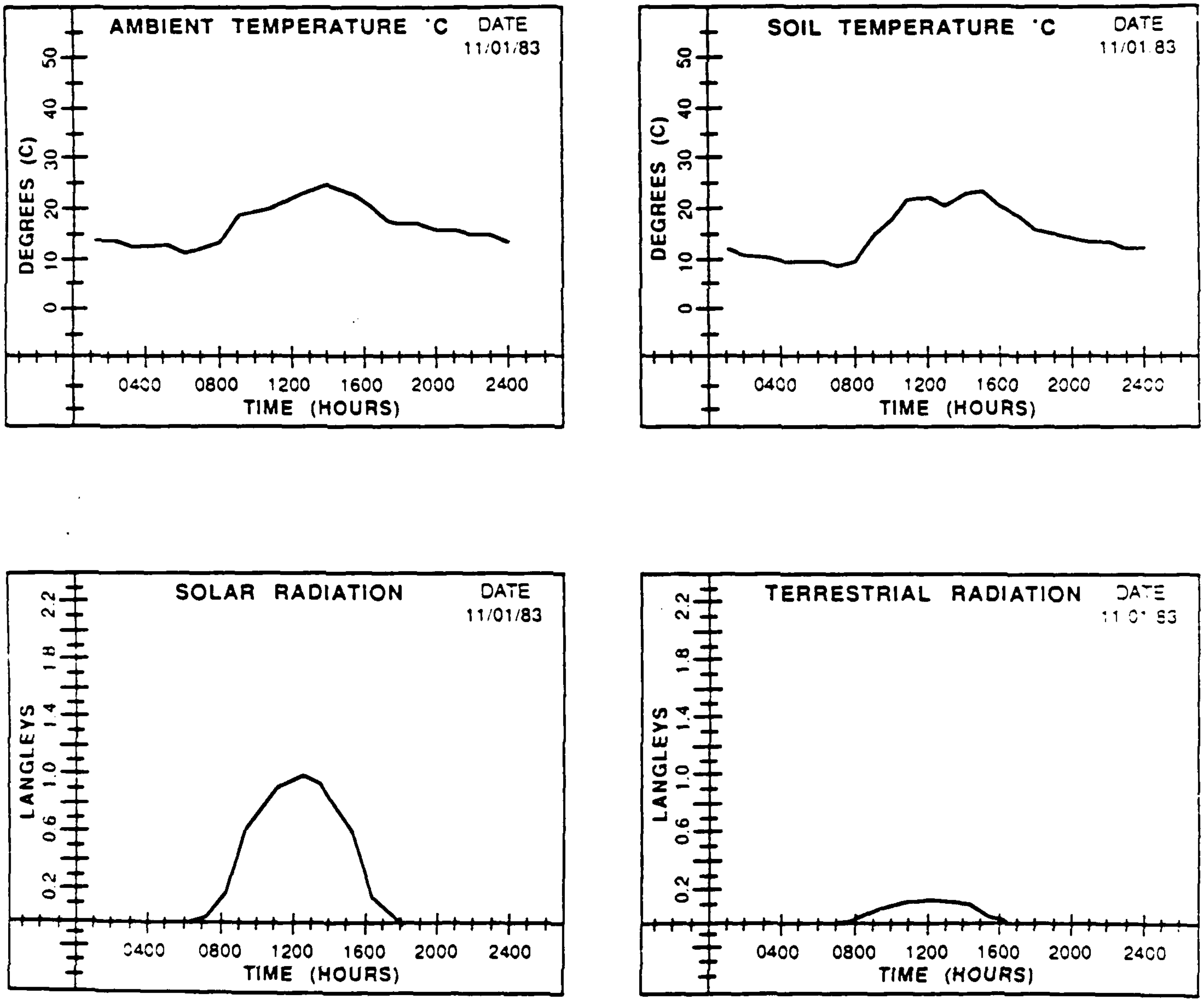

AMBIENT TEMPERATURE °C
DATE 11/01/83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE 11/01.83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000
TIME (HOURS)
SOLAR RADIATION
DATE 11/01/83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0800 1200 1600 2000 2400
TIME (HOURS)
TERRESTRIAL RADIATION
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)

Figure E-7

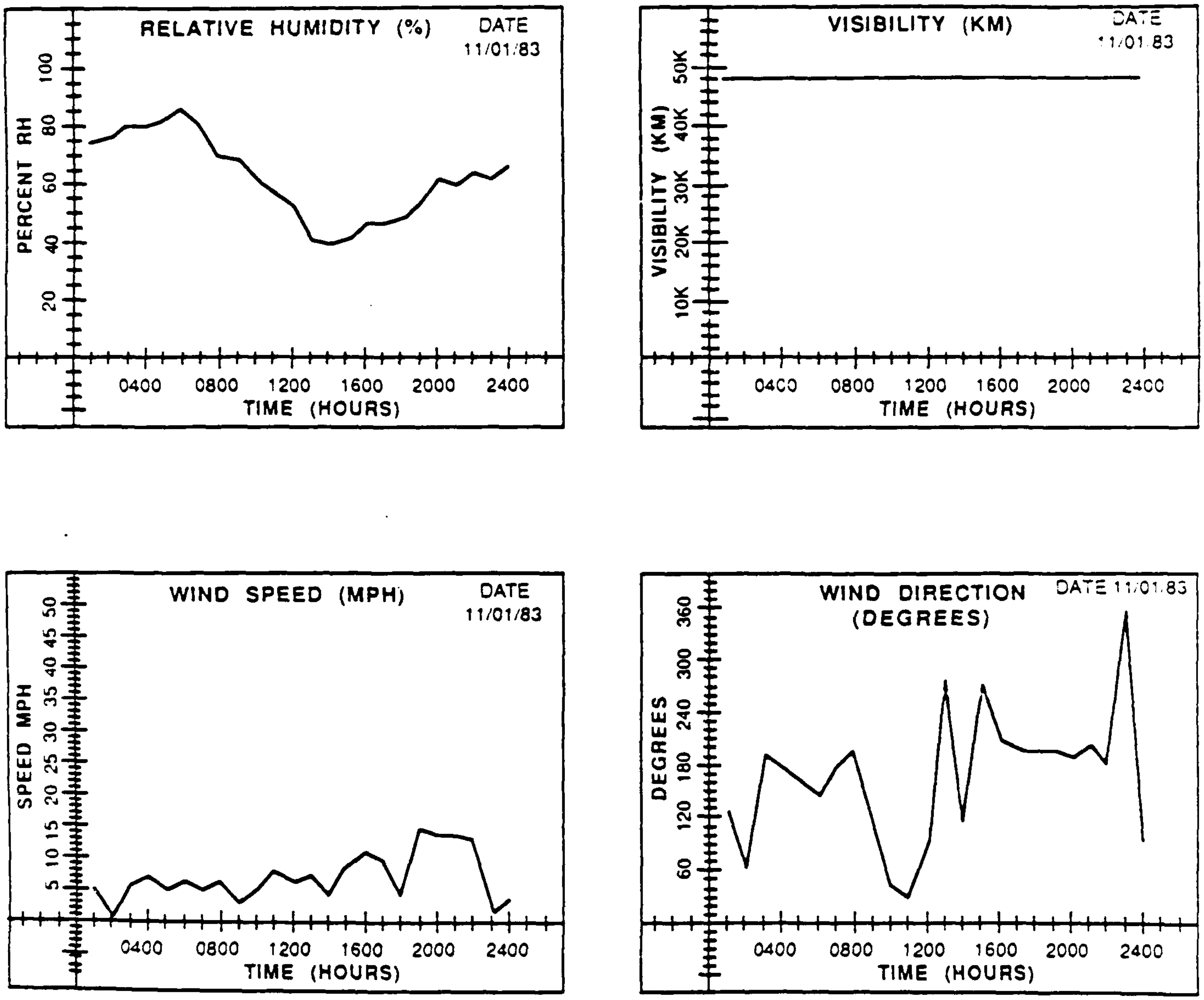


Figure E-7 (continued)

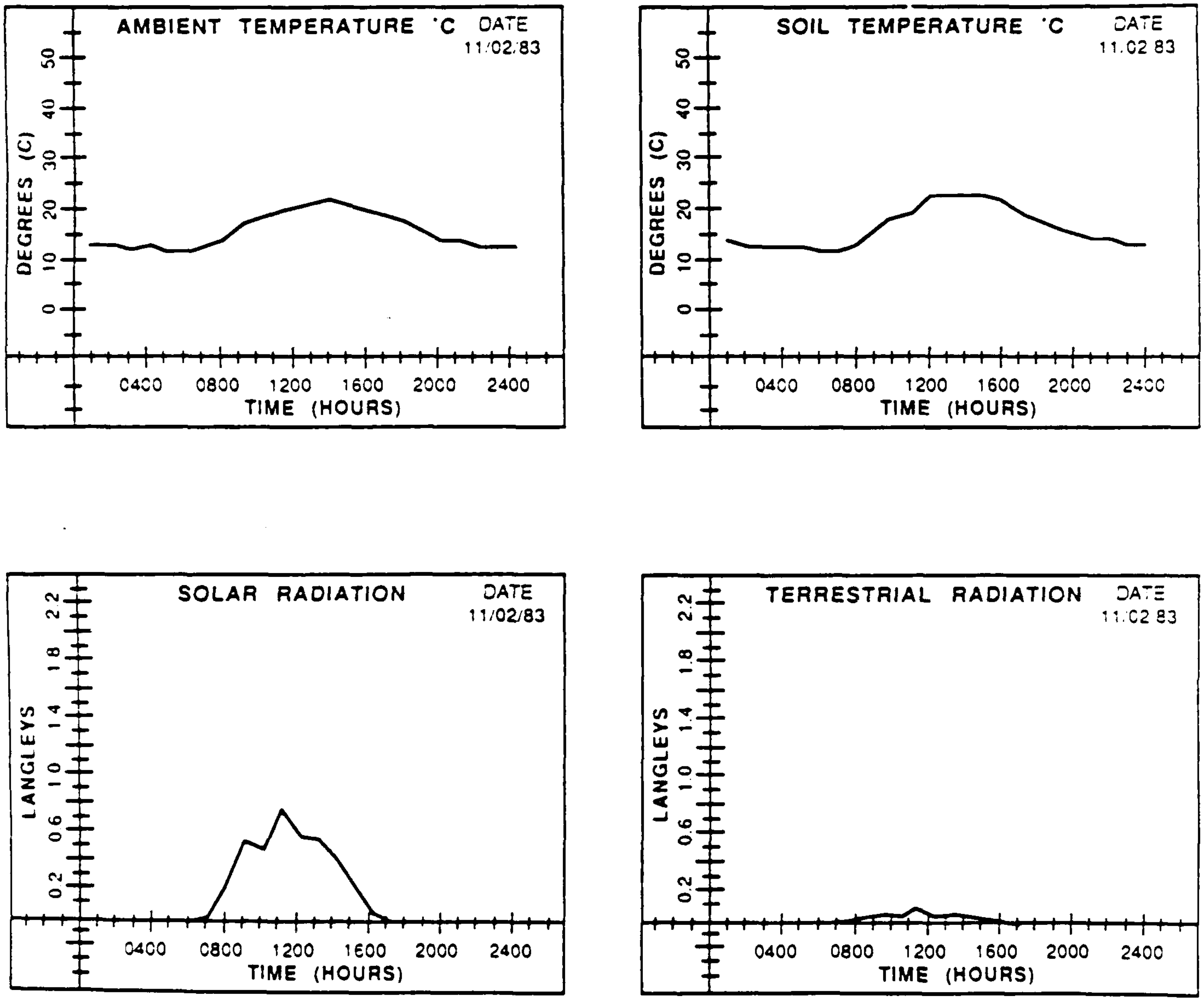

AMBIENT TEMPERATURE °C
DATE 11/02/83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE 11.02 83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOLAR RADIATION
DATE 11/02/83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)
TERRESTRIAL RADIATION
DATE 11.02 83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)

Figure E-8

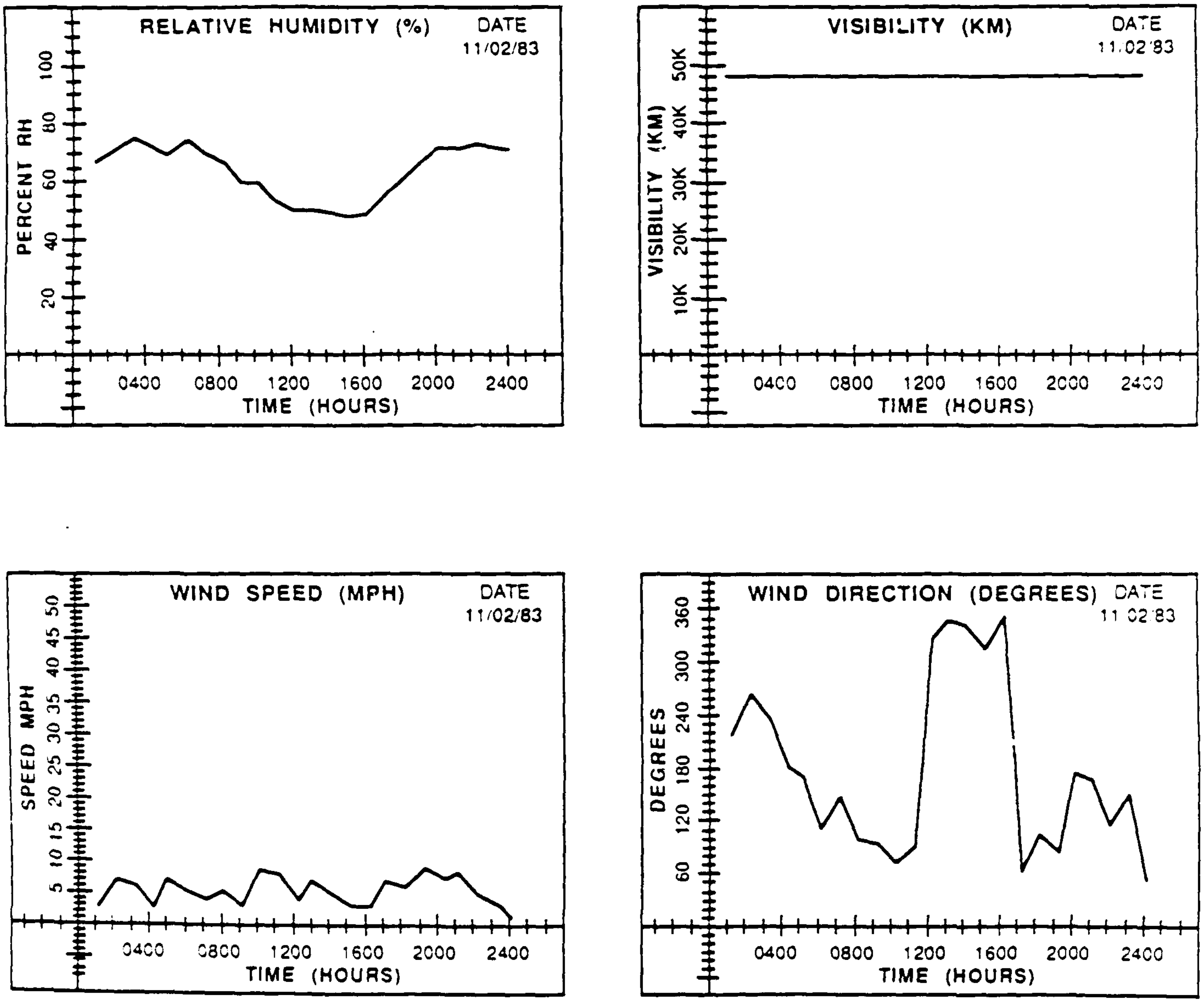


Figure E-8 (continued)

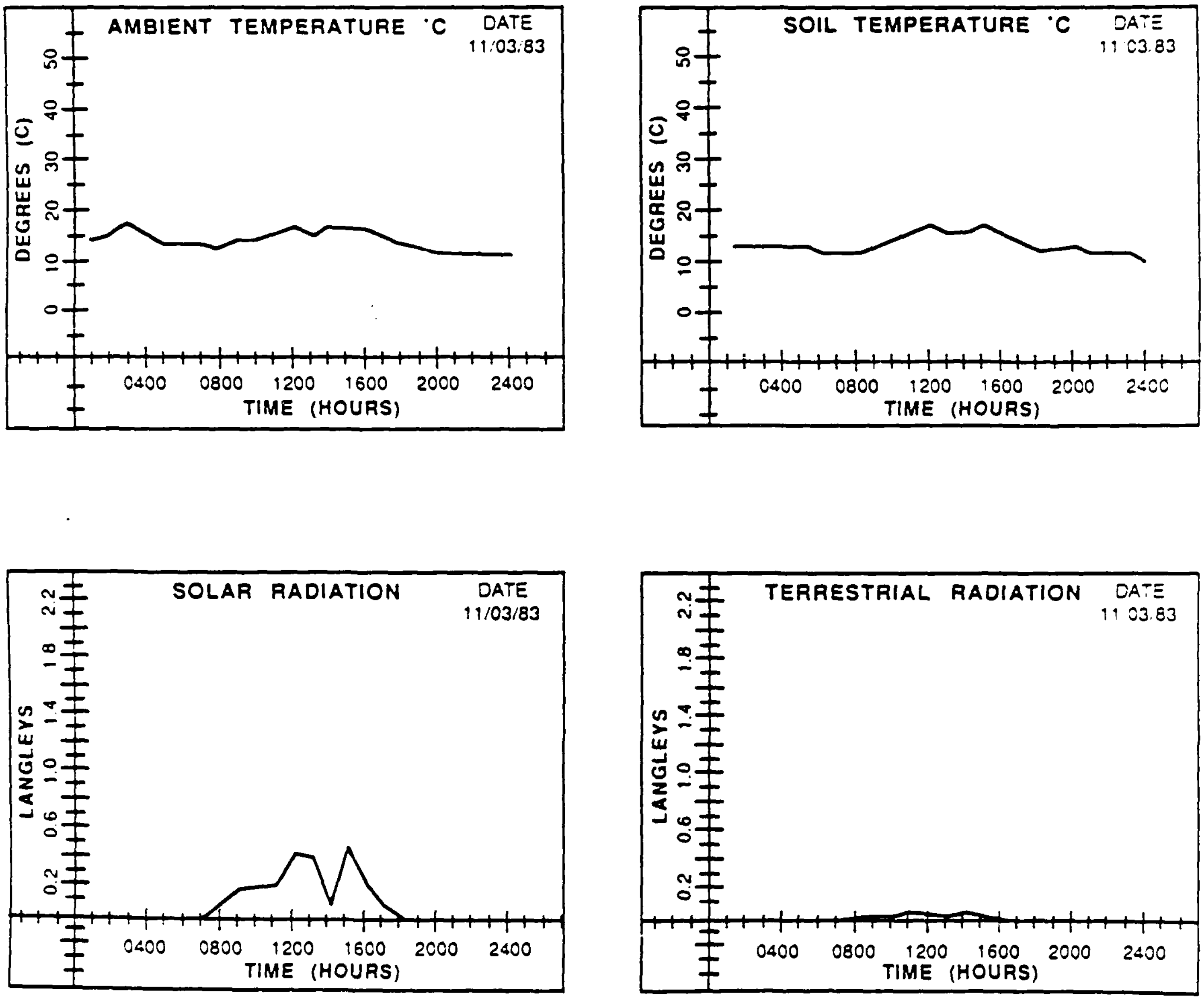

AMBIENT TEMPERATURE °C
DATE 11/03/83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE 11 03 83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOLAR RADIATION
DATE 11/03/83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)
TERRESTRIAL RADIATION
DATE 11 03 83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)

Figure E-9

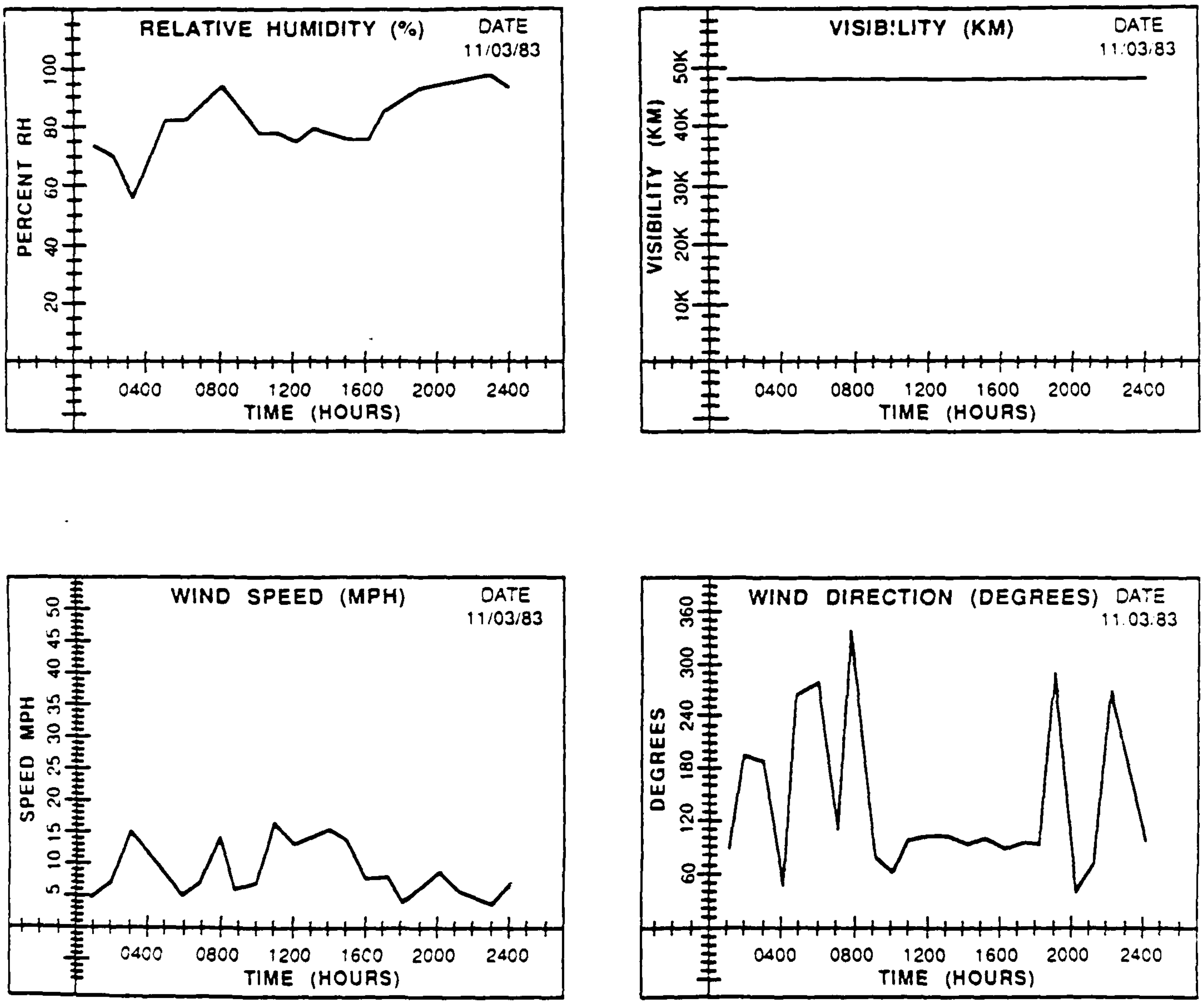


Figure E-9 (continued)

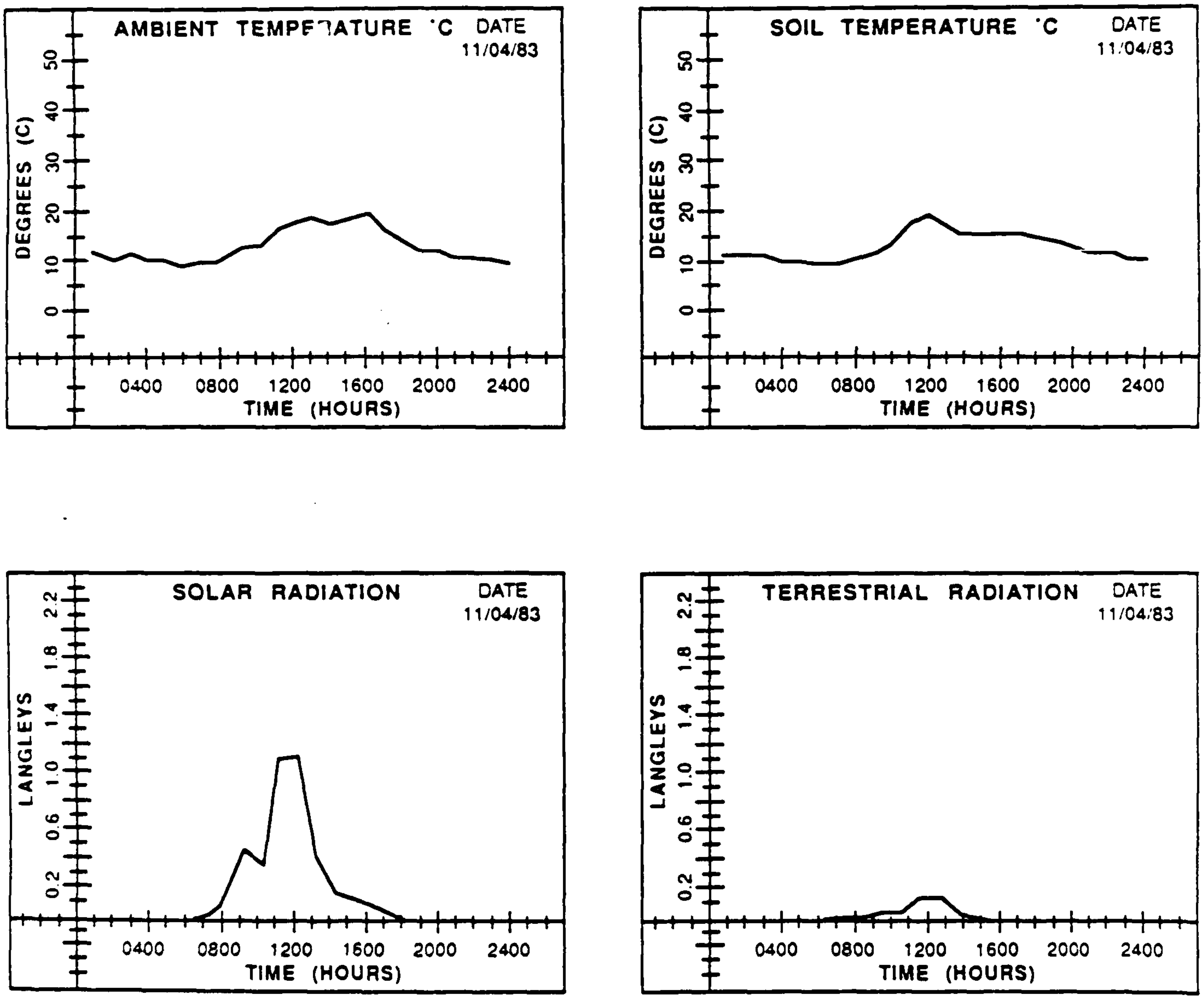

AMBIENT TEMPE?ATURE °C
DATE
11/04/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE
11/04/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOLAR RADIATION
DATE
11/04/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)
TERRESTRIAL RADIATION
DATE
11/04/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)

Figure E-10

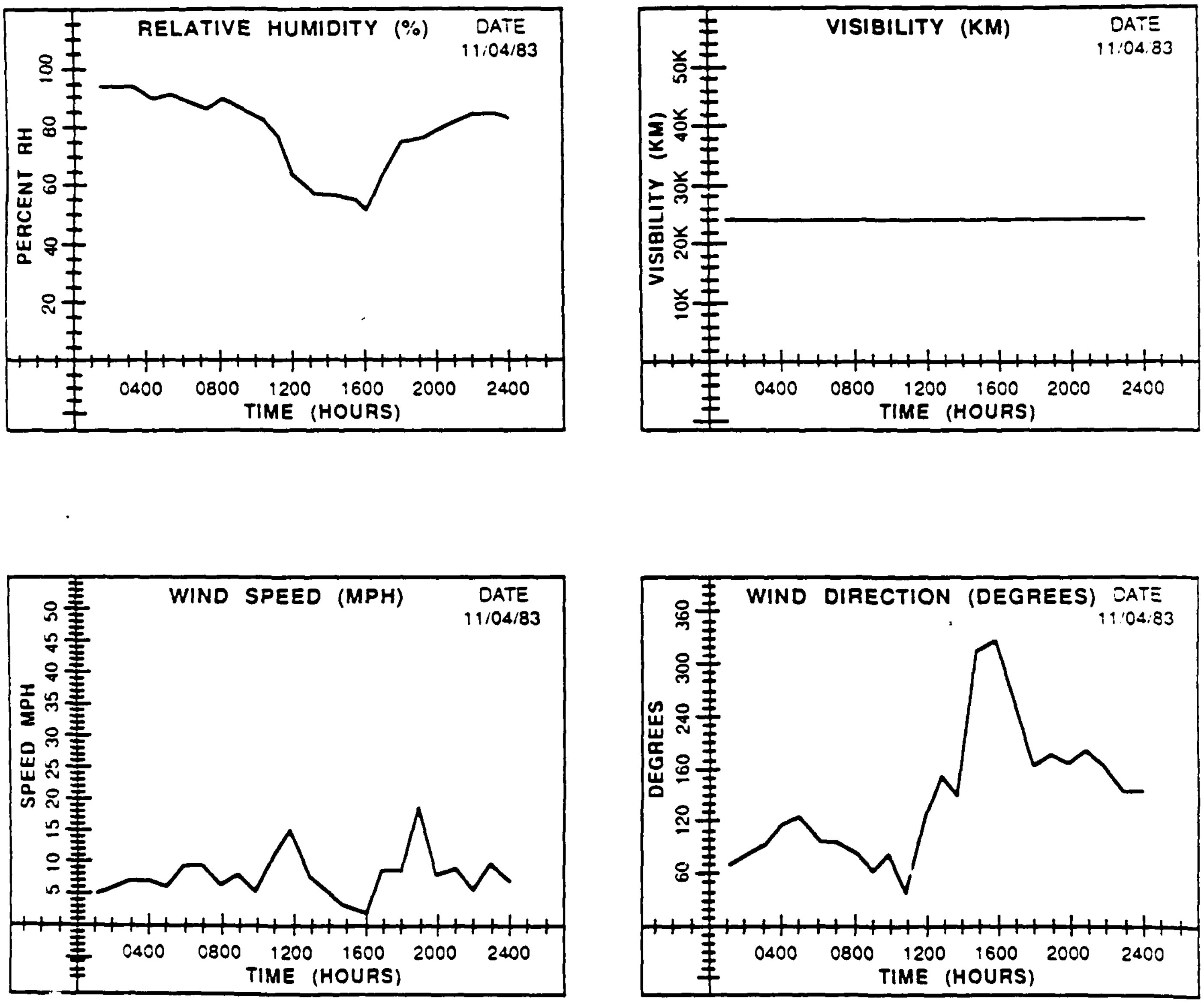


Figure E-10 (continued)

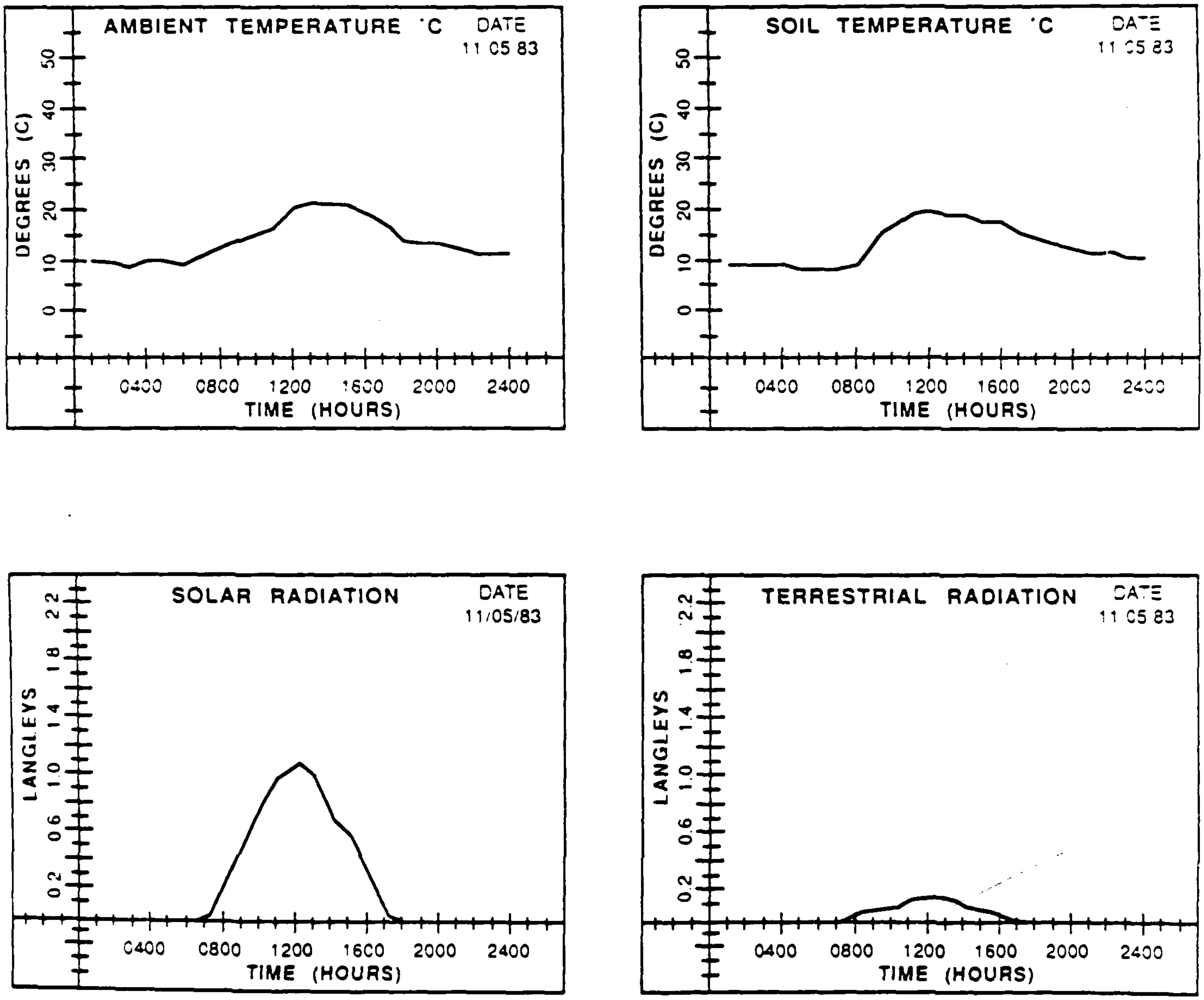

AMBIENT TEMPERATURE °C
DATE
11 05 83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE
11 05 83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOLAR RADIATION
DATE
11/05/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)
TERRESTRIAL RADIATION
DATE
11 05 83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)

Figure E-11

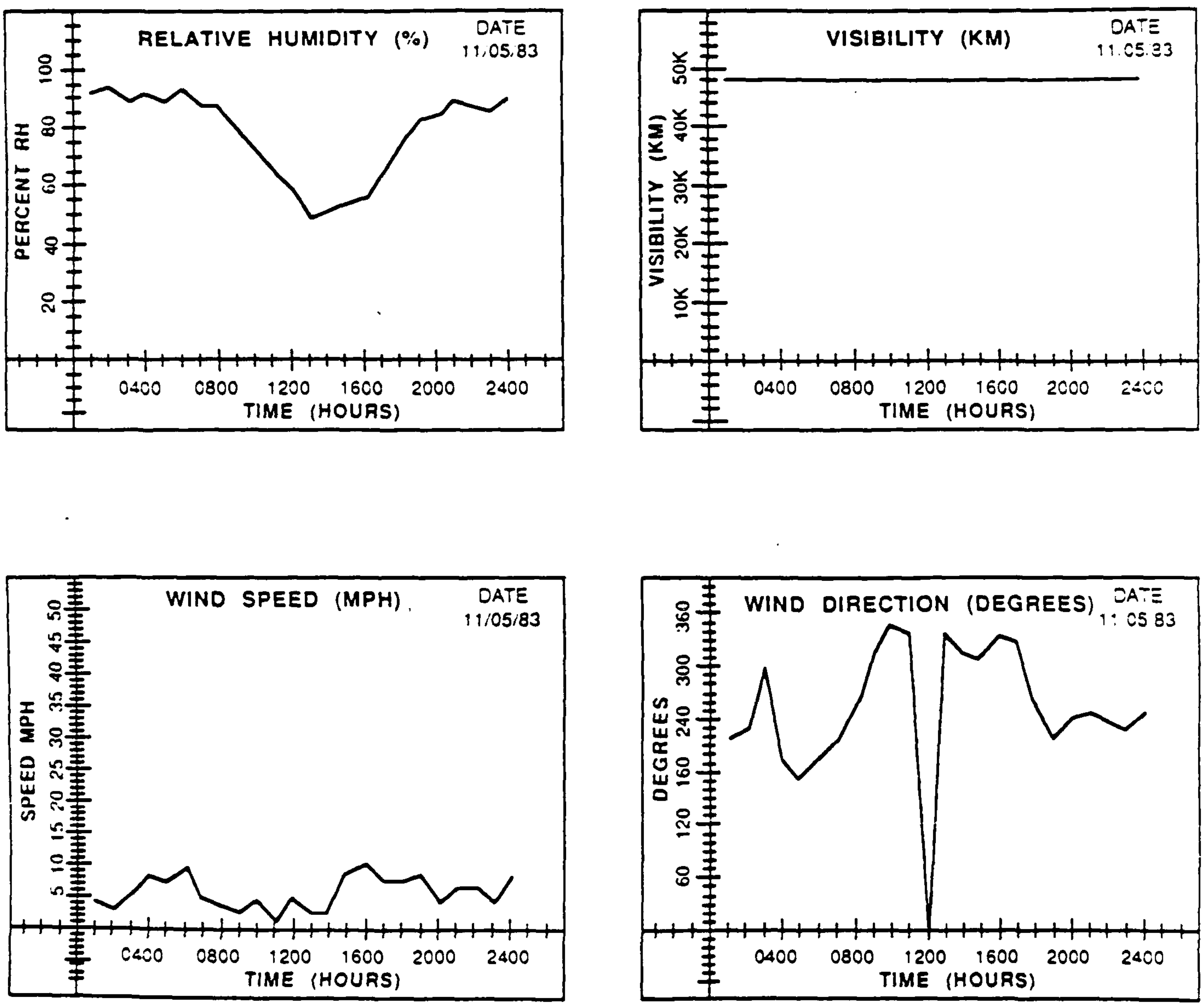
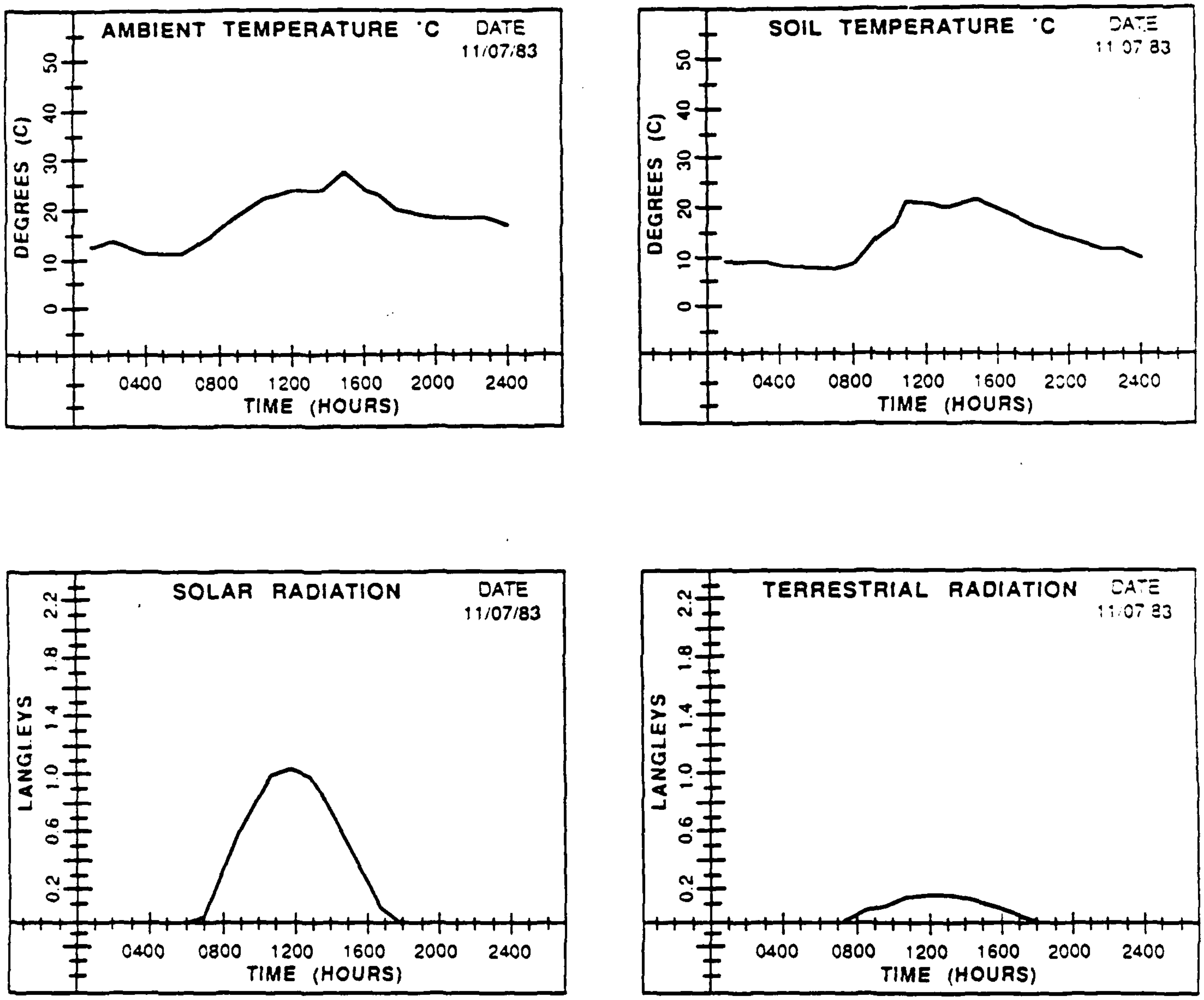


Figure E-11 (continued)



AMBIENT TEMPERATURE °C
DATE
11/07/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2400
TIME (HOURS)
SOLAR RADIATION
DATE
11/07/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)
TERRESTRIAL RADIATION
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
0400
0800
1200
1600
2000
2400
TIME (HOURS)

Figure E-12

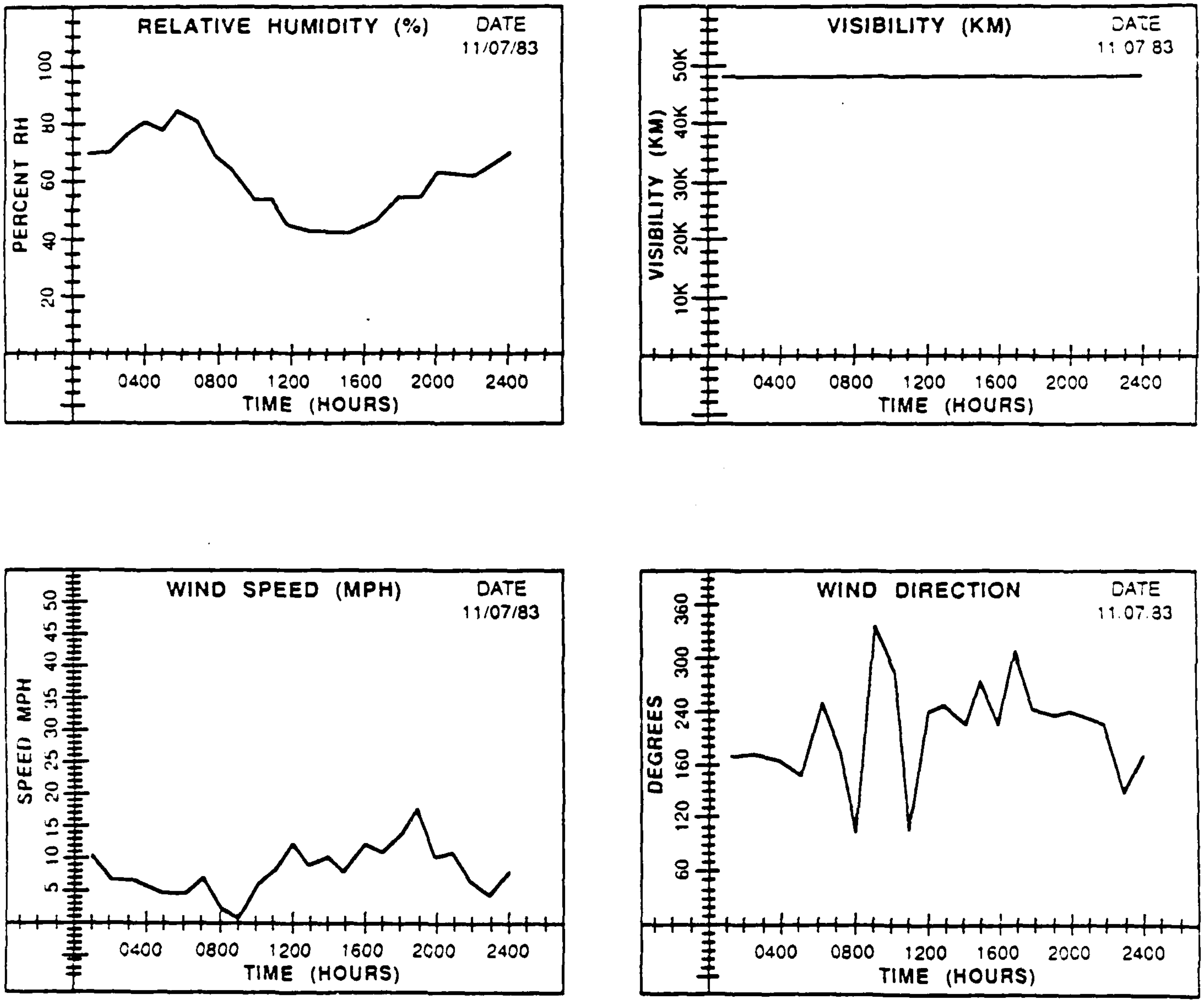


Figure E-12 (continued)

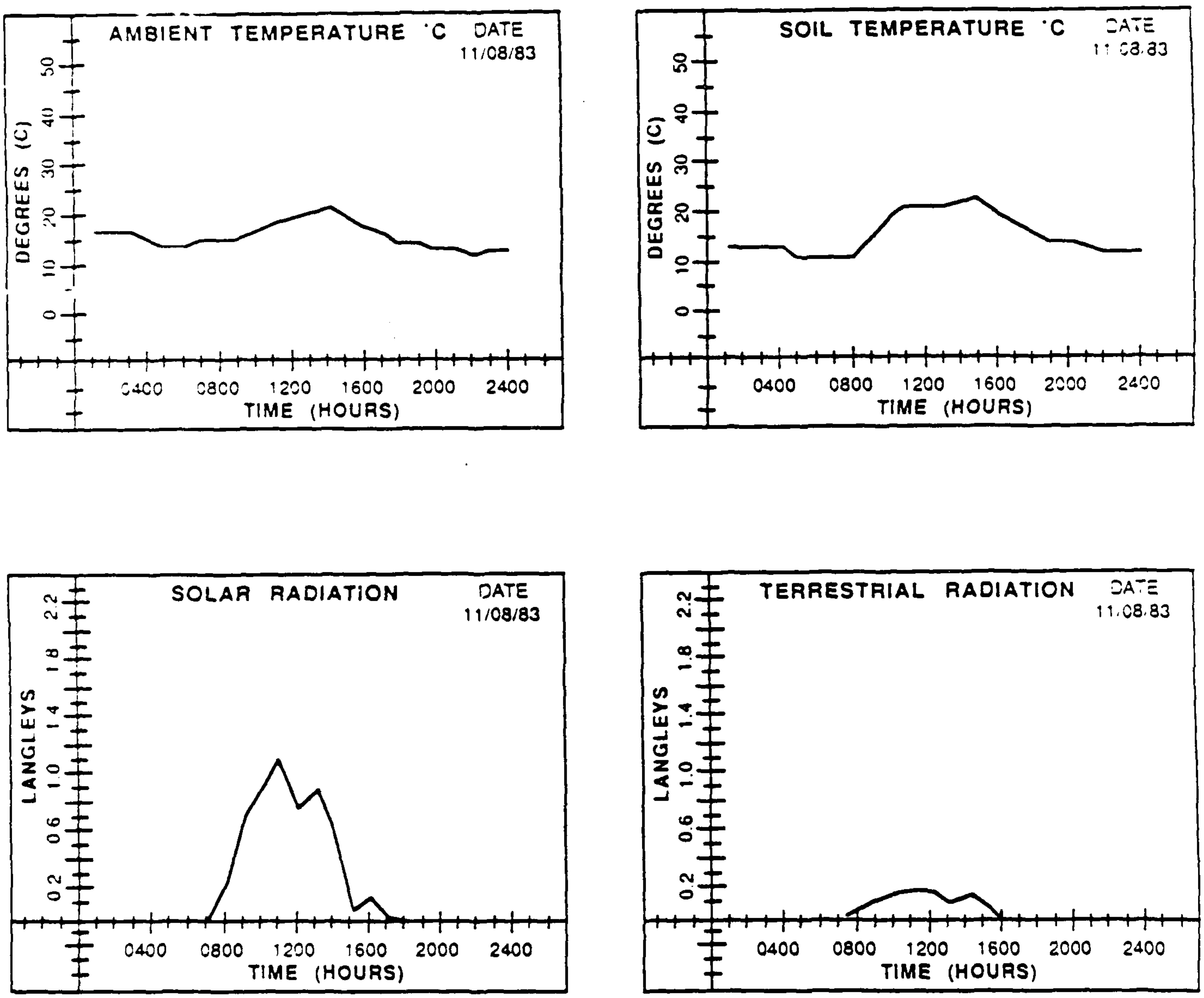

AMBIENT TEMPERATURE °C
DATE 11/08/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DEGREES (C)
SOLAR RADIATION
DATE 11/08/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
TIME (HOURS)
TERRESTRIAL RADIATION
LANGLEYS
TIME (HOURS)

Figure E-13

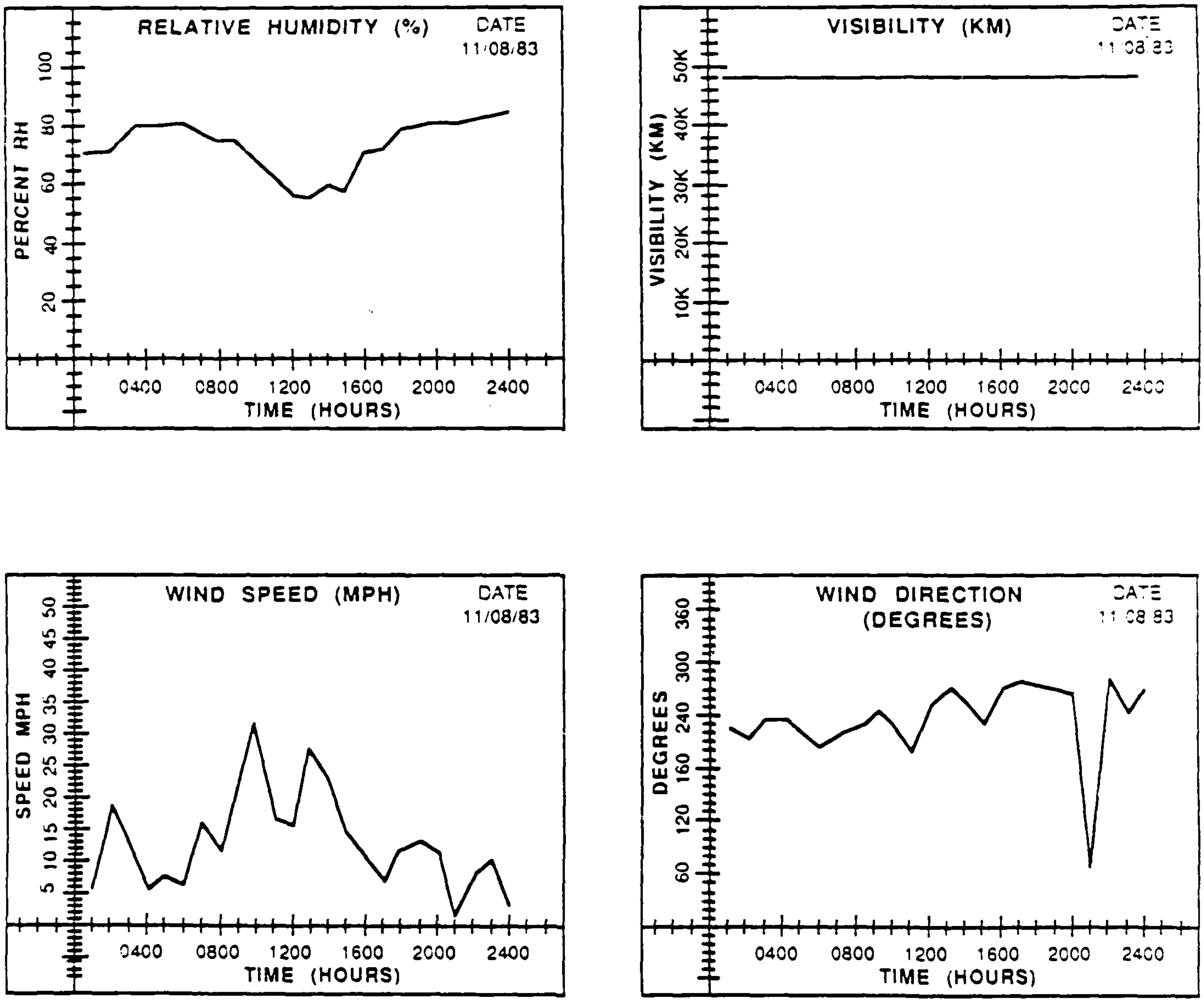


Figure E-13 (continued)

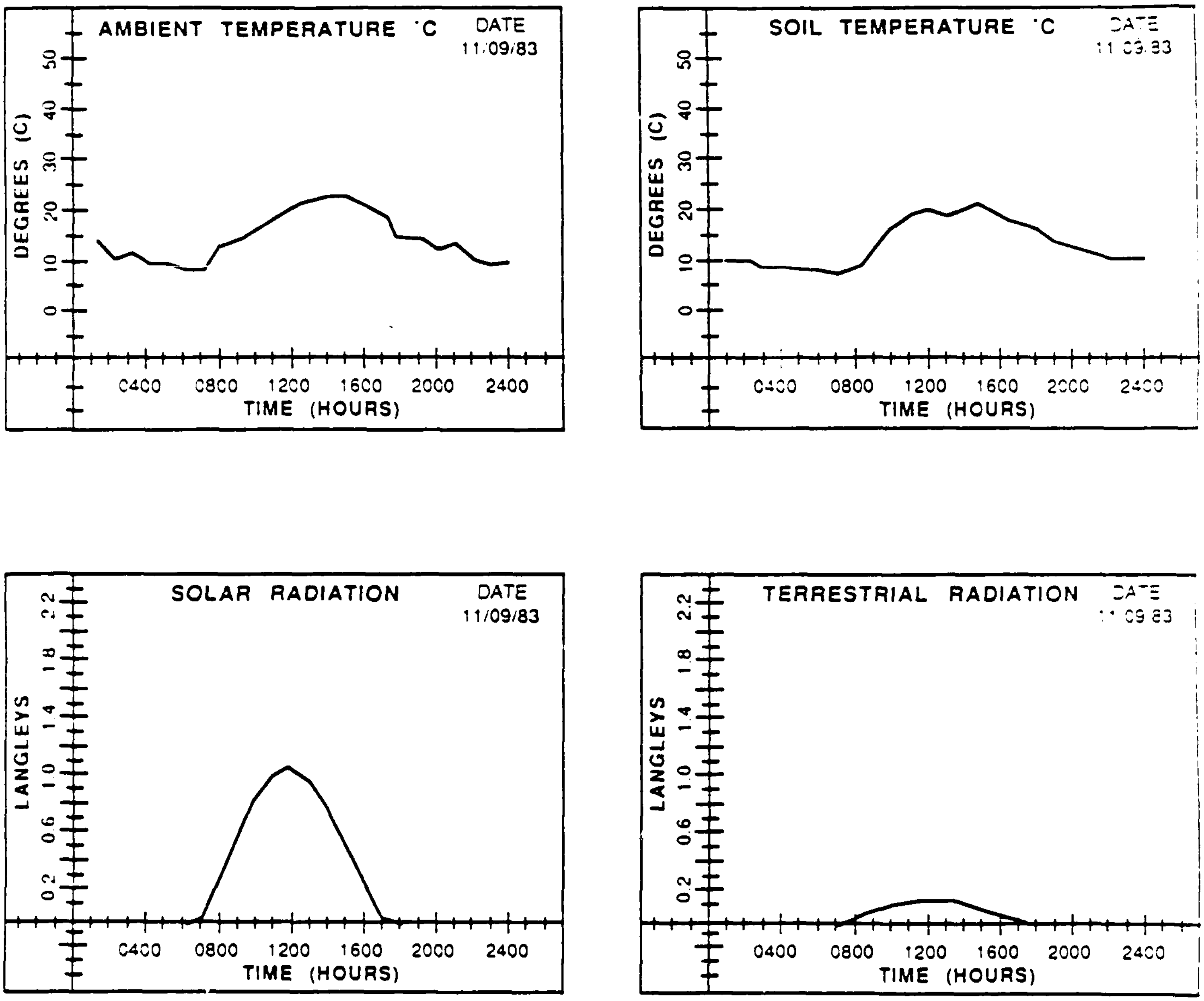

AMBIENT TEMPERATURE °C
DATE
11/09/83
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOIL TEMPERATURE °C
DEGREES (C)
0 10 20 30 40 50
0400 0800 1200 1600 2000 2400
TIME (HOURS)
SOLAR RADIATION
DATE
11/09/83
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)
TERRESTRIAL RADIATION
LANGLEYS
0.2 0.6 1.0 1.4 1.8 2.2
0400 0800 1200 1600 2000 2400
TIME (HOURS)

Figure E-14

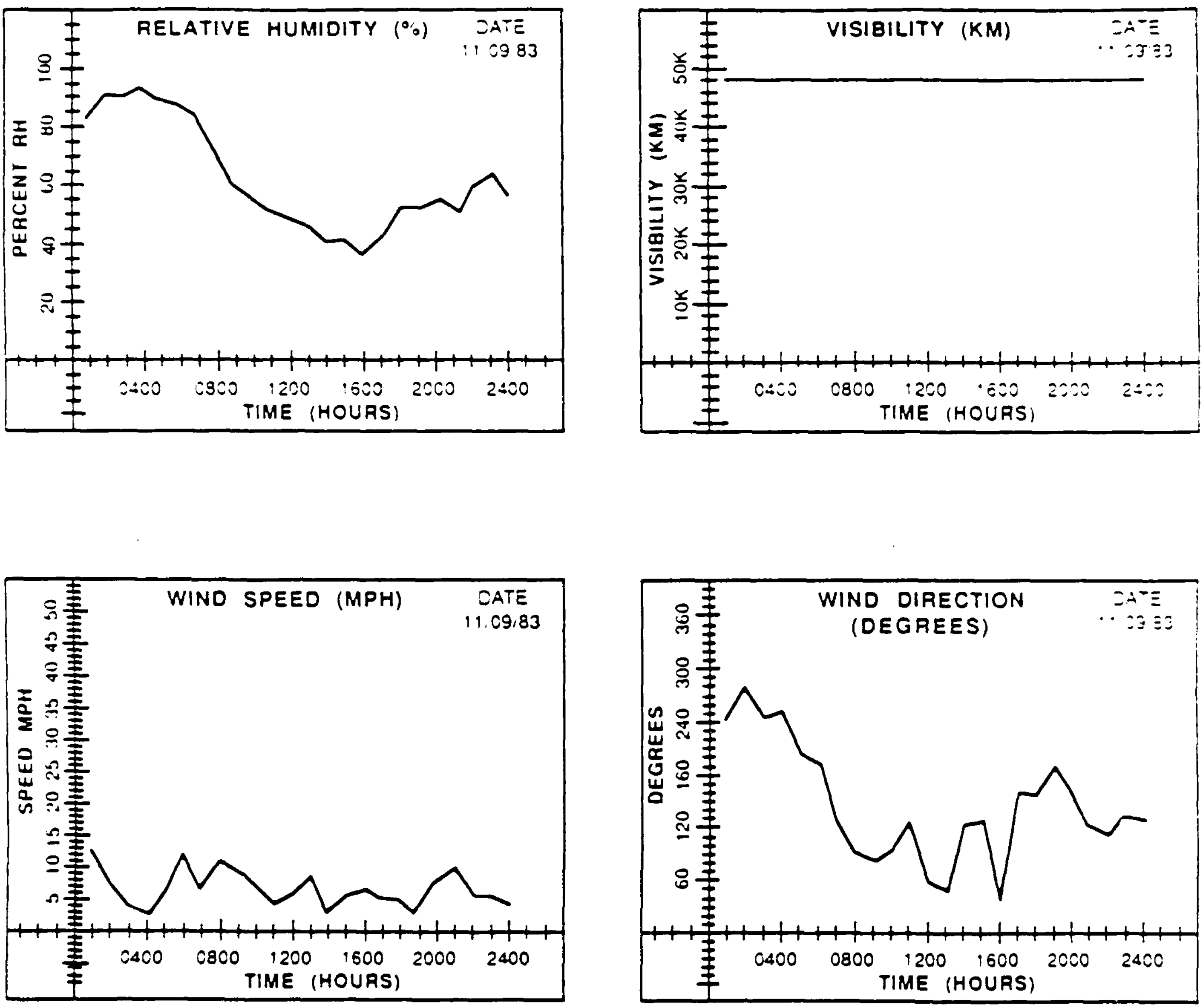


Figure E-14 (continued)

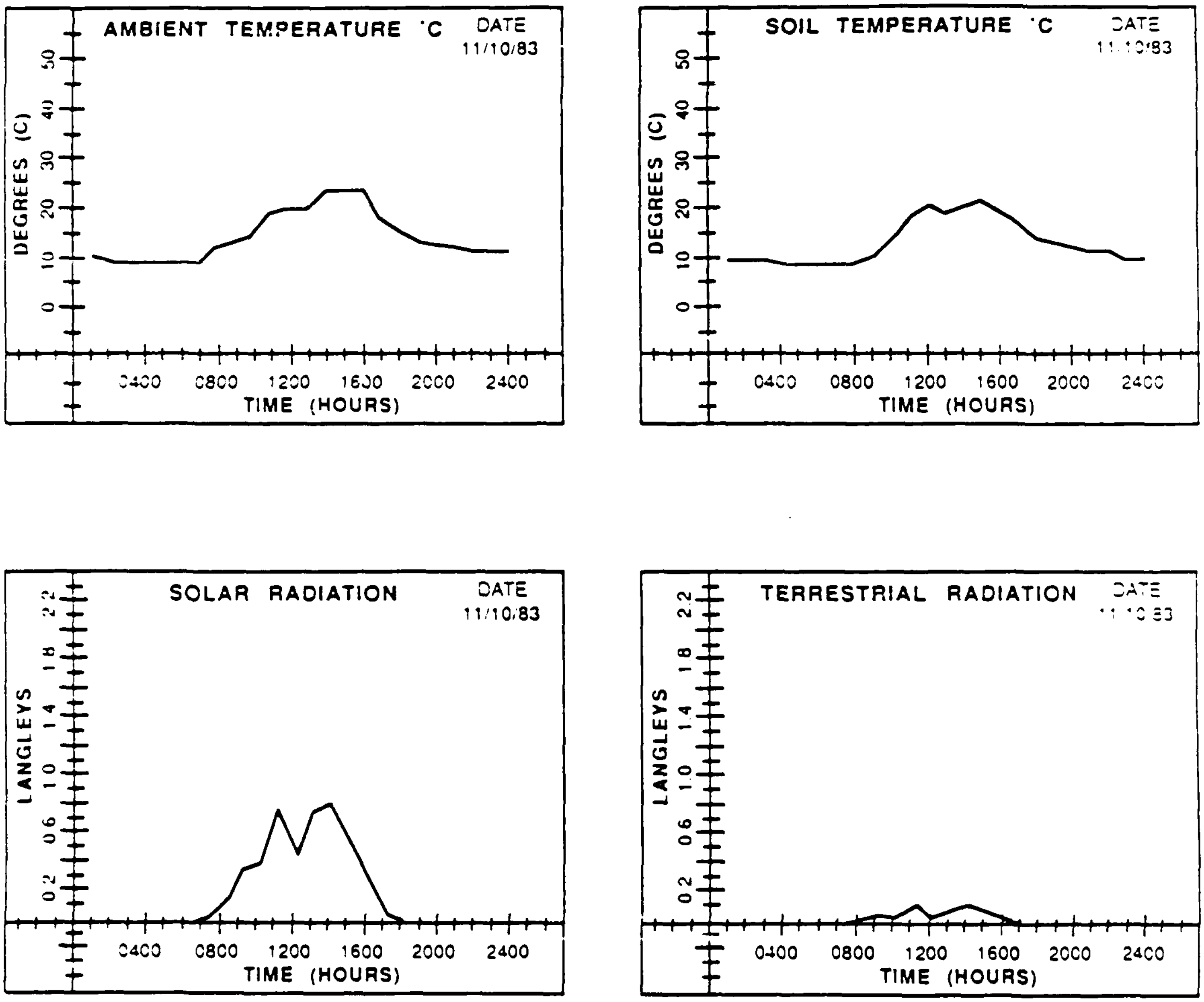

AMBIENT TEMPERATURE °C
DATE 11/10/83
DEGREES (C)
0
10
20
30
40
50
TIME (HOURS)
0400
0800
1200
1600
2000
2400
SOIL TEMPERATURE °C
DATE
DEGREES (C)
0
10
20
30
40
50
TIME (HOURS)
0400
0800
1200
1600
2000
2400
SOLAR RADIATION
DATE 11/10/83
LANGLEYS
TIME (HOURS)
0400
0800
1200
1600
2000
2400
TERRESTRIAL RADIATION
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
TIME (HOURS)
0400
0800
1200
1600
2000
2400

Figure E-15

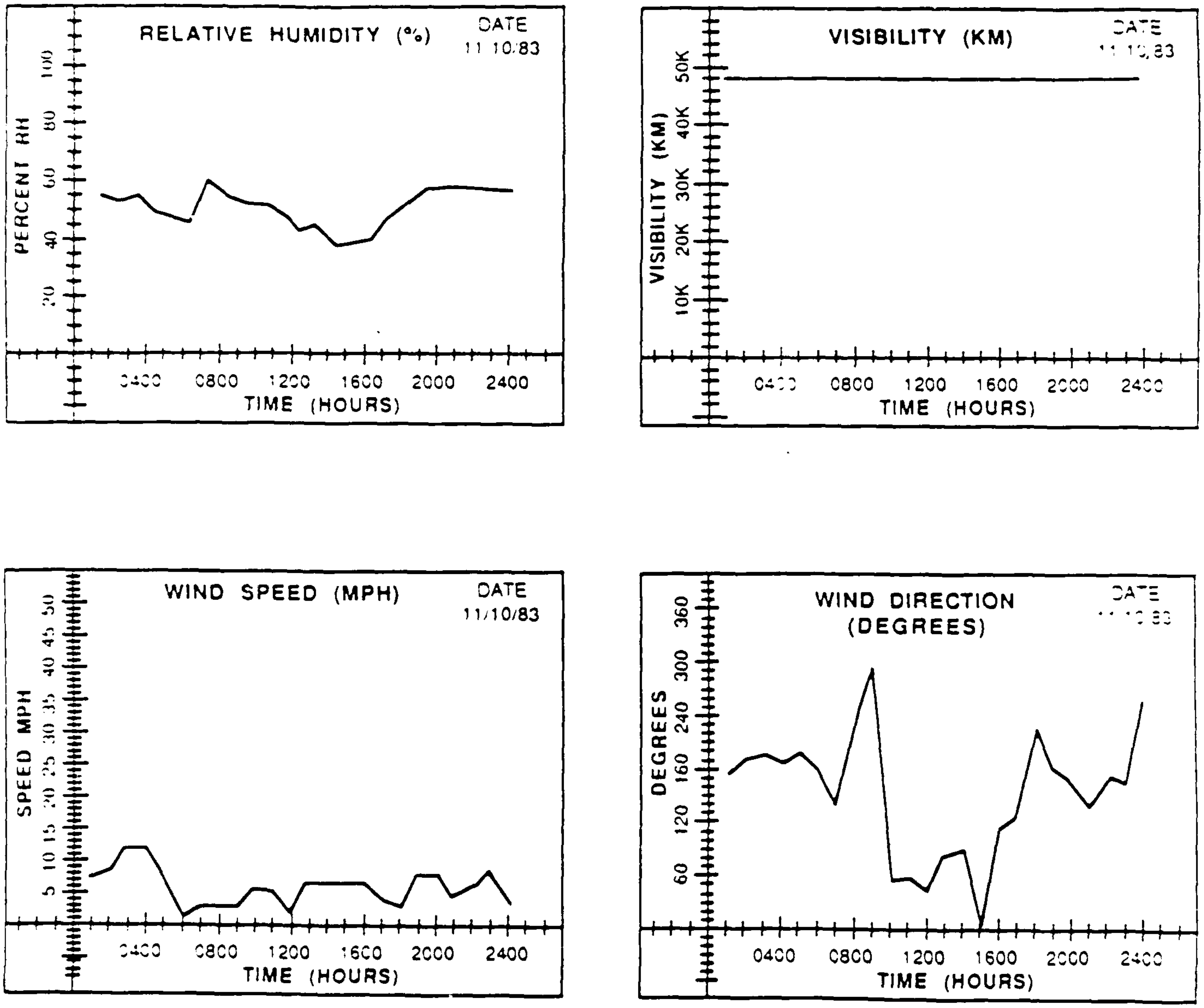


Figure E-15 (continued)

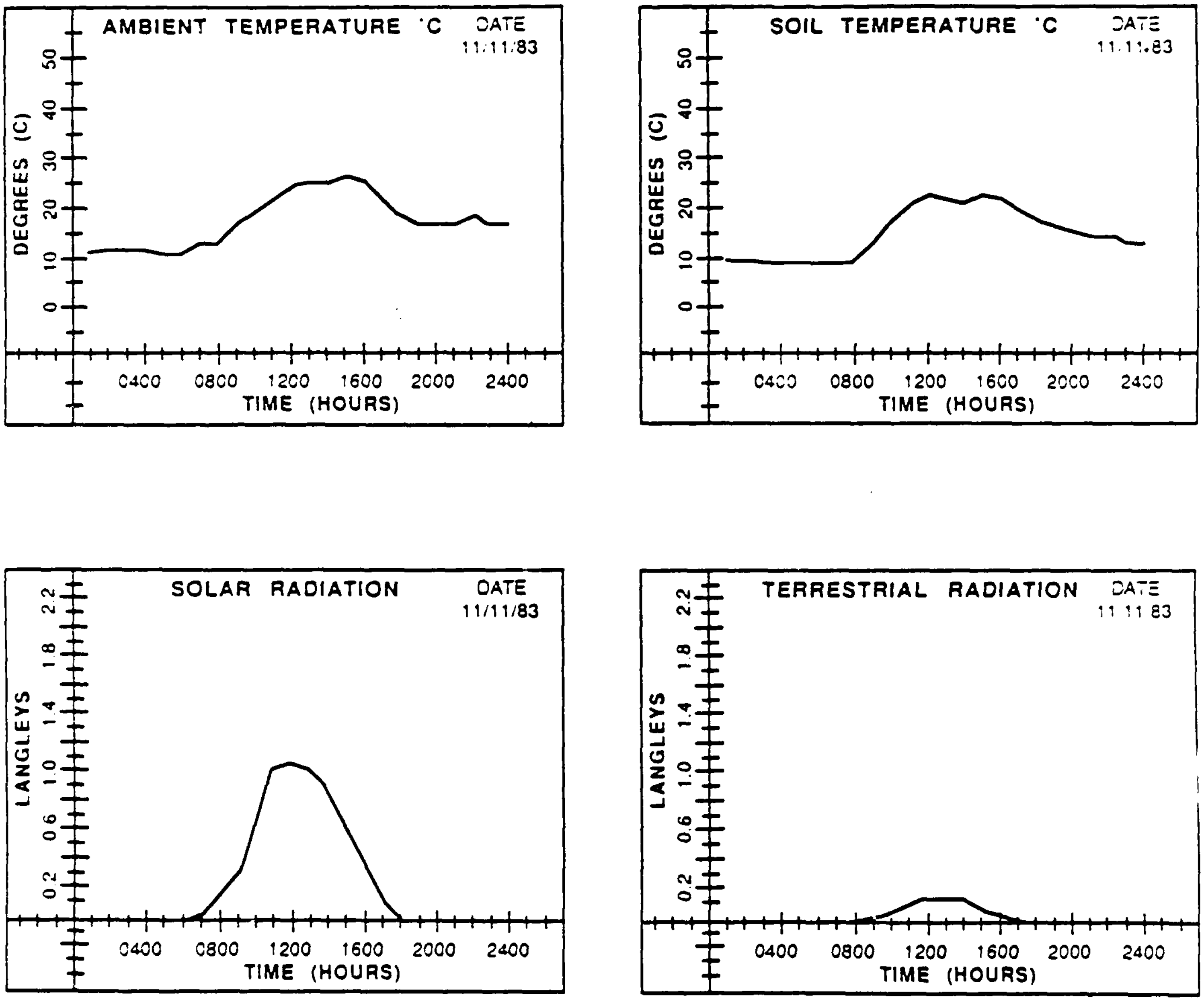

AMBIENT TEMPERATURE °C
DATE
11/11/83
DEGREES (C)
0
10
20
30
40
50
0400
0800
1200
1600
2000
2400
TIME (HOURS)
SOIL TEMPERATURE °C
DATE
DEGREES (C)
TIME (HOURS)
SOLAR RADIATION
DATE
11/11/83
LANGLEYS
0.2
0.6
1.0
1.4
1.8
2.2
TIME (HOURS)
TERRESTRIAL RADIATION
DATE
LANGLEYS
TIME (HOURS)

Figure E-16

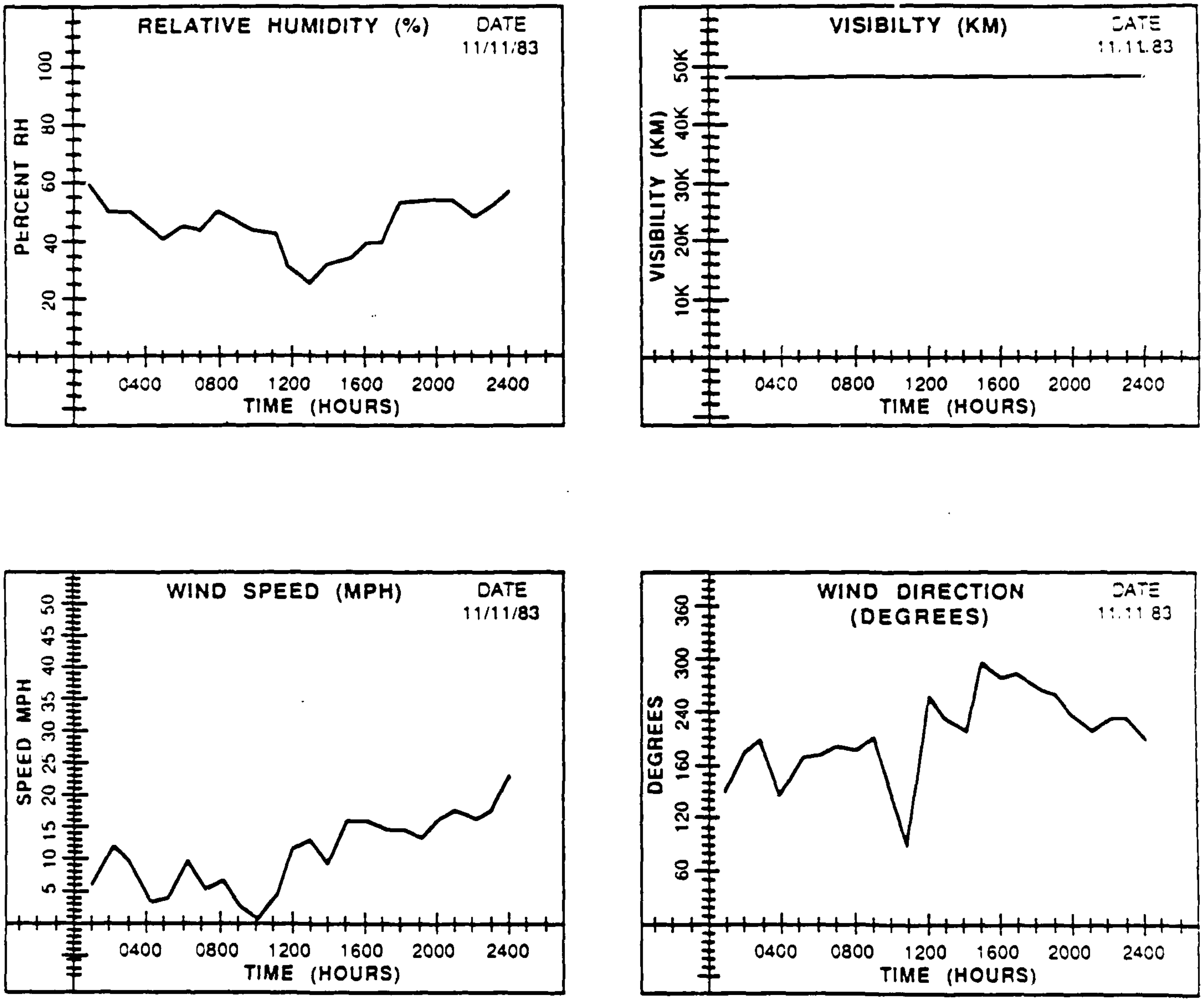


Figure E-16 (continued)

Date 11/12/83:

Graphic Data Unavailable

DISTRIBUTION FOR REPORT NO. 0070

Director
CECOM Center for Night Vision and
Electro-Optics (CNVEO)
20 ATTN: AMSEL-RD-NV-VISD
1 ATTN: AMSEL-RD-NV-ASD
1 ATTN: AMSEL-RD-NV-ISPD
1 ATTN: AMSEL-RD-NV-GSD
1 ATTN: AMSEL-RD-NV-SEMCO
Fort Belvoir, VA 22060-5677

Defense Technical Information Center
3 ATTN: DTIC-FDAC
Cameron Statiion
Alexandria, VA 22304-9990

Commander
US Army Materiel Command
1 ATTN: AMC-PA
Alexandria, VA 22333-0001

Commander
Belvoir RD&E Center
3 ATTN: STRBE-BT (Technical Library)
3 ATTN: ASNK-BPG (Pictorial Spt Div)
Fort Belvoir, VA 22060-5606

Commander
1 USACSC
Fort Belvoir, VA 22060-5677

Director
1 Engineer Topographic Labs
Fort Belvoir, VA 22060

Commander
US Army Training & Doctrine Command
1 ATTN: ATPA
Fort Monroe, VA 23651-5442

Commander
US Army Atmospheric Science Laboratory
1 ATTN: DRSEL-BL-DM
1 ATTN: DELAS-EO
White Sands Missile Range, NM 88002

Director
US Army Training and Doctrine Command
Systems and Analysis Center
1 ATTN: ATOR
White Sands Missile Range, NM 88002

Commander
Vulnerability Assessment Lab
1 ATTN: SLCVA-CFC
White Sands Missile Range, NM 88002

Commander
US Army Tank Automotive Command
1 ATTN: Project Manager, M60 Tank Sys
1 ATTN: AMSTA-RR
Warren, MI 48090-5000

Commander
US Army Communications R&D
Command
1 ATTN: DRDCO-PPA-CA
Fort Monmouth, NJ 00703-5000

Director
Center for EW/RSTA
1 ATTN: AMSEL-RD-EW-D
Fort Monmouth, NJ 07703-5001

Commander
US Army Combined Arms Center
1 ATTN: ATZL
Fort Leavenworth, KS 66027-5050

Commandeer
US Army Infantry Center
1 ATTN: ATSH-CD-MLS
Fort Benning, GA 31905-5065

Commander
Natick RD&E Center
1 ATTN: STRNG
Natick, MA 01760-5000

Commander
US Army Test and Evaluation Command
1 ATTN: AMSTE
Aberdeen Proving Ground,
MD 21005-5055

Commander
Chemical R&D Center
1 ATTN: SMCCR
Building E5101, Edgewood Area
Aberdeen Proving Ground,
MD 21010-5423

Director
US Army Human Engineering Lab
1 ATTN: AMXHE-ST
Aberdeen Proving Ground,
MD 21005-5001

Commander
USAMSAA
1 ATTN: AMXSY-AAM
Aberdeen Proving Ground, MD 21005

Commandant
US Army Armor Center & Fort Knox
1 ATZK-CD-SD
Fort Knox, KY 40121-5000

Commander
US Naval Ordnance Lab/White Oak
1 ATTN: Technical Library
Silver Spring, MD 20910

Commander
Armament Development & Test Center
1 ATTN: DLOSL, Tech Library
Eglin AFB, FL 32542

Commander
US Army Operational Test & Evaluation Agency
1 ATTN: CSTE-STS
5600 Columbia Pike
Falls Church, VA 22041

Commander
US Army Laboratory Command
1 ATTN: SLCHD-PVM
2800 Powder Mill Road
Adelphi, MD 20783

Naval Postgraduate School
Dept of Operations Research
1 ATTN: NPS-55HH
Monterey, CA 93940

1 Commander
Naval Environmental Prediction Research Facility
Monterey, CA 93940

1 Commander
US Army Concepts Analysis Agency
8120 Woodmont Avenue
Bethesda, MD 21004

Commander
Naval Weapons Center
1 Code 3918
China Lake, CA 93555

Commander
Naval Surface Weapons Center
1 Code DG-302
Dahlgren, VA 22448

Commander
US Marine Corps Development Center
1 ATTN: (FPR) MEDEC
Quantico, VA 22134

1 Director
Defense Advanced Research Projects Agcy
1400 Wilson Boulevard
Arlington, VA 22209

Commander
Foreign Science and Tech Center
1 ATTN: DRXST-ESI
220 7th Street, NE
Charlottesville, VA 22901

1 Commander
US Army Engineer Waterways Experimental Station (WES)
Vicksburg, MS 39180

1 Naval Test Center
Systems Engineering Test Directorate
Building 1403
Patuxent River, MD 20670

1 Commander
US Army Intelligence Center & School
Fort Huachuca, AZ 85613

1 Office of the Deputy Undersecretary of Defense for Research and Advanced Technology
Room 3D1079, Pentagon
Washington, DC 20310

HQ, Dept of the Army
1 Deputy Undersecretary of the Army (R&D)
Pentagon
Washington, DC 20310

Commander
HQ, TRADOC
Combined Arms Test Activity
1 ATTN: ATCT-SCI
Fort Hood, TX 76544-5065

1 Commander
US Army Test & Evaluation Command
Fort Ord, CA 93941

1 Commander
Avionics Laboratory
Wright-Patterson AFB, OH 45433

Director
Aviation Applied Technology Directorate
USAARTA (AVSCOM)
1 ATTN: SAVRT-TY-ASW
Fort Eustis, VA 23604

Commander
US Army Aviation Systems Command
1 ATTN: AMCPM-LHX-TA
4300 Goodfellow Boulevard
St. Louis, MO 63120

Commander
US Army Aviation Systems Command
1 ATTN: AMCPM-LXH-TA
4300 Goodfellow Boulevard, MO 63120

Commander
AVRADA
1 ATTN: SAVAA-F
Fort Monmouth, NJ 07703

Commander
USAAUNG
1 ATTNM: ATZQ-CDC-LX
Fort Rucker, AL 36322