LEVEL II

2

5C

AD A089896

AD

RDTE PROJECT NO/NSN

TECOM PROJECT NO 5-CO-YPO-ITA-811

TEST AGENCY PROJECT/REPORT NO 397

TEST SPONSOR

TEST SPONSOR PROJECT NO

TRADOC A.C.

INFRARED TARGET ARRAY DEVELOPMENT

by

EDWARD A. SCOTT

April 1980

Distribution Unlimited

U. S. ARMY YUMA PROVING GROUND

YUMA, ARIZONA

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 5-CO-YPO-ITA-811	2. GOVT ACCESSION NO. AD-A089 896	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Infrared Target Array Development,		5. TYPE OF REPORT & PERIOD COVERED FINAL rept, Oct 1978-Mar 1980
		6. PERFORMING ORG. REPORT NUMBER 397
7. AUTHOR(s) Edward A./Scott	YPG-397	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Yuma Proving Ground ATTN: STEYP-MMI Yuma, AZ 85364		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 71
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Test & Evaluation Command ATTN: DRSTE-AD-I Aberdeen Proving Ground, MD 21005		12. REPORT DATE Apr 1980
		13. NUMBER OF PAGES 68
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Target	YAH-64	Advanced Attack Helicopter
Thermal	Infrared	Resolution
Detection	Recognition	Laser Scoring

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The US Army Yuma Proving Ground (USAYPG) was requested under TECOM Project No. 5-CO-YPO-ITA-811 to develop and acquire a series of infrared targets with controllable thermal signatures to support the test and evaluation of the Target Acquisition Designation System/Pilot Night Vision System (TADS/PNVS) subsystems of the Advanced Attack Helicopter (AAH) Fire Control System. Prior to this development effort, no capability beyond the use of real-scene targets existed at USAYPG to provide thermally active targets with characteristic signatures in the infrared band. (CONTINUED)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED 383

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Three targets were acquired: (1) a detection target, (2) a recognition target, and (3) a laser scoring board.

It is concluded that design goals were met and the system was delivered in time to perform its function. The system provides sufficient thermal realism and has advanced the state-of-the-art of infrared imaging system test and evaluation.

It is recommended that the ~~FEBT~~ system be validated as a potential test standard and that environmentally "hardened" targets be acquired for continued thermal sight testing.

Field Equivalent Bar Target (FEBT)

Accession For
NTIS
DTIC
Unannounced
Justification

By
Distribution
Availability
Dist
A

TABLE OF CONTENTS

APPENDICES

ABSTRACT

The U.S. Army Yuma Proving Ground (USAYPG) was requested under TECOM Project Number 5-CO-YPO-ITA-811 to develop and acquire a series of infrared targets with controllable thermal signatures to support the test and evaluation of the Target Acquisition Designation System/Pilot Night Vision System (TADS/PNVS) subsystems of the Advanced Attack Helicopter (AAH) fire control system. Prior to this development effort, no capability beyond the use of real-scene targets existed at USAYPG to provide thermally active targets with characteristic signatures in the infrared band.

Three targets were acquired: (1) a detection target, (2) a recognition target, and (3) a laser scoring board.

It is concluded that design goals were met and the system was delivered in time to perform its function. The system provides sufficient thermal realism and has advanced the state-of-the-art of infrared imaging system test and evaluation.

It is recommended that the FEBT system be validated as a potential test standard and that "hardened" targets be acquired for continued thermal sight testing.

FOREWARD

This report covers the acquisition of the Field Equivalent Bar Target System under TECOM Project 5-CO-YPC-ITA-811, Infrared Target Array Development.

The contributions of the following people, without whom this project would not have been completed, are gratefully acknowledged:

a. Mr. Robert Elmore, USAYPG Instrumentation Program Manager, for obtaining the funding for system acquisition and initiating the feasibility analyses leading to the development of the Field Equivalent Bar Target System.

b. Mr. Warren Sanborn, USAYPG Procurement Directorate, for his expertise in contractual matters.

c. Mr. Tom Werneking, White Sands Missile Range, NM and Mr. Dick Moody, U.S. Army Electronic Proving Ground, for their quick responses to specialized instrumentation loan requirements.

d. Messrs Don Newman and Tom Cassidy, U.S. Army Night Vision and Electro-Optics Laboratory, for their technical assistance.

e. Messrs. Wally Moore and Chuck Ramsdell, USAYPG Aircraft Armament Branch, and the USAYPG "gunners"for their expert assistance in target assembly.

f. Mr. Lee Masse, USAYPG Photo-Optics Section, and Messrs. Terry Wood, Bob Hohman, and Bill Isbell, Bell Technical Staff, for their excellent documentation work.

1. INTRODUCTION

1.1 INTRODUCTORY REMARKS

The U.S. Army Yuma Proving Ground was selected as the site for the competitive "fly-off" of the Target Acquisition Designation System/Pilot Night Vision System (TADS/PNVS) subsystems, designed by the Martin Marietta and Northrop Corporations for the YAH-64, Advanced Attack Helicopter (AAH). Site selection was based upon many factors, some of which were the consistently good flying weather over Yuma (360+ days) and the ease of modelling the Yuma climate and the subsequently derived optical parameters for insertion into the various modelling programs to determine and verify system performance.

Competition "fly-off" occurred from approximately 2 January through 31 March 1980. During the competition, it is estimated that data acquired from the thermal targets, the Field Equivalent Bar Targets, accounted for approximately 10% of the data collection flying time.

The following report will discuss the acquisition of the Field Equivalent Bar Target System used in the competition.

1.2 BACKGROUND

The Department of the Army (DA) is in the process of development and deployment of attack helicopter systems such as the Advanced Attack Helicopter (AAH). Their primary function will be to provide direct aerial fire against a wide variety of enemy tactical targets.

The AAH fire control system includes the Target Acquisition Designation System (TADS) and the Pilot Night Vision System (PNVS). The primary subsystems of the TADS are a Forward-Looking Infrared (FLIR) device, TV, Direct View Optics, Laser Designator, and Laser Range Finder, all mounted on a stabilized platform. The PNVS is a navigational and fire control device consisting principally of a FLIR device. One of the primary requirements of the AAH fire control system is to enable the acquisition and designation of targets at extended ranges in conditions of varying visibility, to include day, night, fog, haze and smoke.

In order to assess the night vision facets of this capability, target arrays with controllable thermal signatures were required.

2. PROGRAM OBJECTIVES

The objectives of the program as developed during the acquisition process were identified as:

2.1 Determine Infrared Target Array Requirements: A preliminary investigation was conducted to assess the U.S. Army Yuma Proving Ground (USAYPG) requirements for range targets with controllable thermal signatures to support testing of the subsystems of the AAH fire control system. Analysis resulted in requirements for three types of targets: (1) Detection, (2) Recognition, and (3) "Aim Point Cross" or Laser Scoring Board.

2.2 Prepare Infrared Target Array specifications: A systems specification for the series of three Field Equivalent Bar Targets (FEBT) was formulated from the requirements analysis.

2.3 Develop Infrared Target Array: Prior to the initiation of this project, an active element thermal bar target was a device used only in the laboratory. It was the objective of this development to prove the feasibility of extrapolating a laboratory measurement technique to a field test environment. Consequently, a contract for development and fabrication of the infrared target array (DAAD01-79-C-0037) was let to TVI Corporation, Kensington, Maryland on 3 July 1979 and delivery was effected on 30 November 1979 with final acceptance testing completed on 6 December 1979.

3. DETAILS OF TASK

3.1 ACQUISITION

3.1.1 TASK METHODOLOGY

Because one of the primary requirements of the Advanced Attack Helicopter fire control system is to enable the acquisition and designation of targets at extended ranges in conditions of varying visibility, e.g. day, night, fog, haze, and smoke, USAYPG was requested under TECOM Project No. 5-CO-YPO-ITA-811 to develop and acquire a series of infrared targets with controllable thermal signatures. Prior to this development effort, no capability, beyond the use of real-scene targets, existed at USAYPG to provide thermally active targets with characteristic signatures in the infrared band. Thermal realism was desired to efficiently test the specified parameters of the fire control system. Specifically, this development and acquisition task was accomplished in three phases:

a. Requirements Analysis

b. Specification Preparation

c. Development

3.1.2 REQUIREMENTS ANALYSIS

An initial review by USAYPG personnel of the AAH fire control documentation indicated that specialized expertise not available at USAYPG would be required to formulate Infrared Target Array requirements. Consequently, Contract No. DAAD01-78-M-1557 (Reference 1) was let in April, 1978, to Dr. William Wolfe of Infrared Incorporated, Tucson, Arizona, to provide an assessment of USAYPG requirements for range targets and to provide advice and guidance on target design, target utilization and the associated measurement instrumentation. Dr. Wolfe's study resulted in a series of system requirements and the suggestion of several alternative fabrication techniques.

3.1.3 SPECIFICATION PREPARATION

The requirements generated by the Infrared Incorporated study were independently subjected to analysis by the U.S. Army Night Vision and Electro-Optics Laboratory, Fort Belvoir, Virginia (NV&EOL). The requirements identified a need for special equipments and materials. Consequently, a survey of industry conducted by NV&EOL in February 1979 revealed that a proprietary product manufactured by the TVI Corporation of Kensington, Maryland under the trade name of ENERGY KOTE (Reg. trademark) offered the only known source capable of providing the required degree of thermal control in a light weight, field portable, resolution pattern target. A specification was drafted for the Field Equivalent Bar Target System. Three types of targets were identified for acquisition:

a. A Detection Target

b. A Recognition Target

c. An "Aimpoint Cross" or Laser Scoring Board

3.1.4 DEVELOPMENT

Request for Proposal (RFP) No. DAAD01-79-R-0054 was issued on 11 May 1979, resulting in Contract No. DAAD01-79-C-0037 on 3 July 1979 with the TVI Corporation, Kensington, Maryland.

3.2 DESCRIPTION OF MAIN COMPONENTS

3.2.1 DEVELOPMENT METHODOLOGY

The idea of controllable thermal bar patterns for use in a field test environment was suggested by NV&EOL in response to the requirement for an Infrared (IR) Imaging and Control System. The Field Equivalent Bar Target (FEBT) System is used for comparison testing of infrared and near-infrared optical and electro-optical systems.

Ideally, the basic experimental scheme would be to station a real scene object, such as a tank, at a particular identifiable point and fly towards the object along a predetermined flight path. When the observer (pilot) notes that an object is present, detection has occurred. Recognition occurs when the class to which the object belongs has been discerned; e.g., tank, truck, man. Identification occurs when the observer can fully describe the object to the limit of his knowledge; e.g., T-62 Tank, friendly APC (Reference 2).

Functionally, threshold resolution can be related to the visual discrimination of images of real scenes. This may be accomplished by replacing the real scene object with a bar pattern of contrast similar to that of the object (Figure 1). The number of bars in the pattern can then be correlated to the criteria of detection, recognition, etc.; i.e., correlation with the sensor's threshold bar pattern resolution. The bar spacing is some function of the minimum dimension of the scene object and the level of desired visual discrimination (Reference 3). Testing against targets such as the FEBT system, obviously, does not allow duplication of the full realism of an operational environment; however, such testing does test competitive systems at less expense than would full scale field tests against real scene objects.

NV&EOL has developed an extensive modelling technique for analyzing and projecting sensor performance against a military target. This technique indicates that the recognizability of a military target using a given sensor is related to an equivalent contrast or temperature difference bar pattern whose bar spacing is some function of the minimum dimension of the object and the level of visual discrimination desired. For the example of a side view of a tank, height is the dimension of interest. In addition, the NV&EOL modelling technique adjusts the length of the bars to the length of the target so that the energy of the bars will be considered over the equivalent length of the real target. Consequently, if a system has been specified to perform a given level of recognition against a 2.3 by 2.3 meter target, it is then necessary to construct a panel that is one-half cycle more than the criterion high and 2.3 meters long. A half cycle is defined as (target dimension) /(the number of lines specified for the criterion), where criterion is detection, recognition, etc.* The test is the degree to which the observer is able to resolve all the individual bars in the pattern. Because of this resolution requirement, the FEBT for the detection criterion must consist of three one-half cycles (2 bars separated by an equivalent distance), but only the target dimension in length. The reason for the extra one-half cycle on each target is that the pattern should begin and end on a "background" bar. This is done so that a "target" bar is not left contrasted to the material background. A similar rationale may be developed if width is assumed to be the dimension of interest in a frontal view of the tank. See references 2, 3, and 7 for a rigorous discussion of the substitution of bar pattern resolution targets for real-scene objects.

* The terms and criteria of visual acuity are identified in Tables 1 and 2.

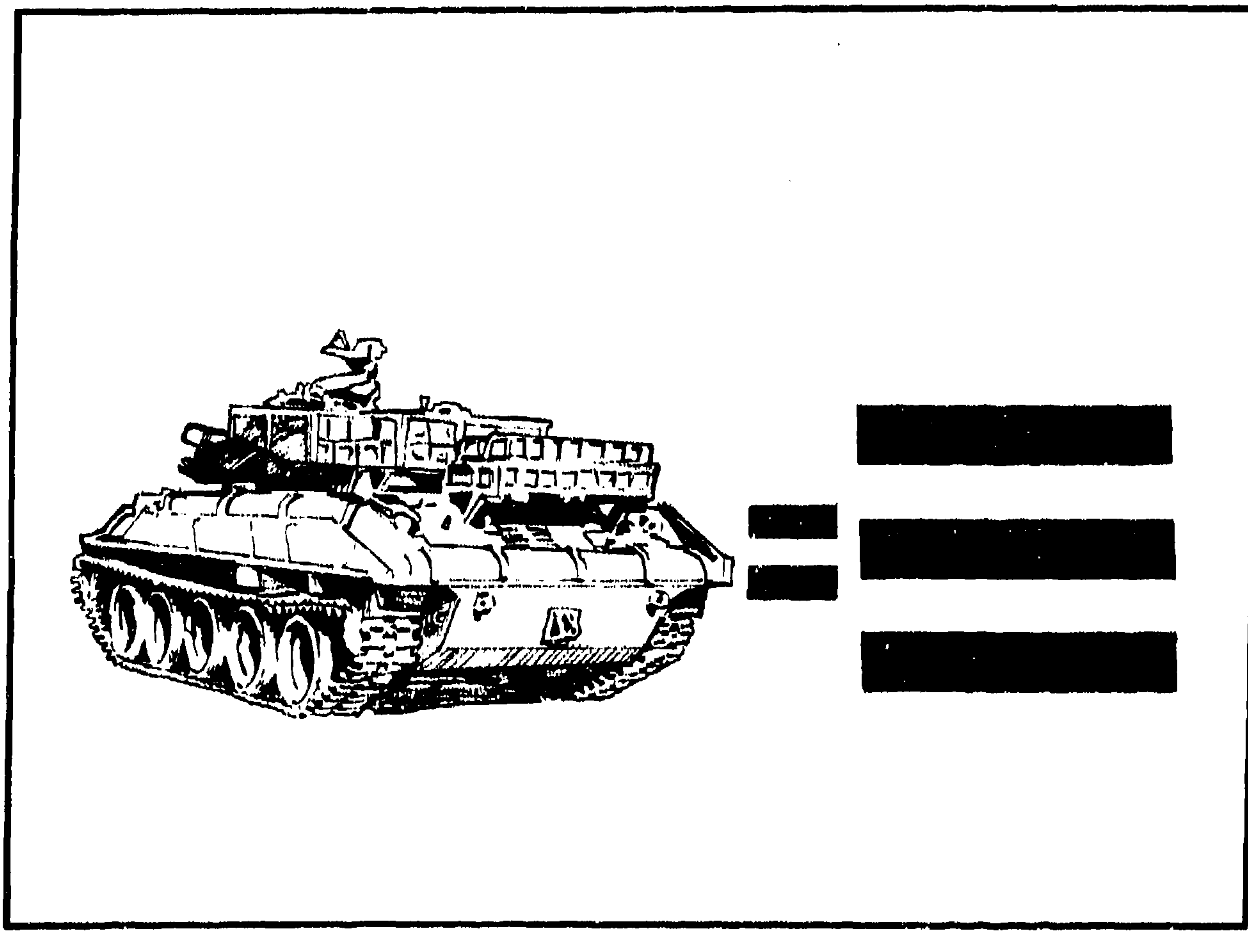


Figure 1

BAR PATTERN APPROACH
TO RESOLUTION
VS
DESIRED LEVEL OF
VISUAL DISCRIMINATION

Table 1 - Levels of Visual Discrimination (Reference 2)

Discrimination Task	Level	Description	Example
Detection	0	A blob has been discerned that may or may not warrant further investigation. Probability of false alarm is high.	A bright spot in a scene may be a tank, a smudge pot, a tree, an animal, a campfire, etc. No appreciable cues.
	1	A blob has been discerned that has a reasonable probability of being the object sought, because of auxiliary but limited cues that definitely warrant further investigation if possible. Probability of false alarm is moderate.	A stationary blob on a road has a reasonable probability of being a vehicle but could also be a puddle or a tree shadow
	2	A blob has been discerned that has a high probability of being the object sought because of strong cues such as location, motion, radiant signature, and reported location scale. Evidence is sufficient to abandon other search. Probability of false alarm is low to moderate.	A blob moving at high speed on the horizon sky has a high probability of being an aircraft. A hot moving object on a road is probably a vehicle.

Table 1--Continued

Type Recognition	3	An object has been discerned with sufficient clarity that its general class can be differentiated.	Differentiate between a tracked and a wheeled vehicle.
Classical Recognition	4	An object has been discerned with sufficient clarity that its particular class can be definitely established.	Passenger car, van, pickup truck, tank, armored personnel
Identification	5	An object has been discerned with sufficient clarity not only to establish the particular class of object but also, the specific type within the class.	M-60 tank, F-4 aircraft, a particular person, etc.

Table 2 - Resolution Required for Various Levels of Visual Discrimination (Reference 2)

Discrimination Task	Level	Estimated Resolution Required per Minimum Object Dimension (lines or half cycles)
Detection	0	1-3
	1	2-4
	2	2-5
Type Recognition	3	4-10
Classical Recognition	4	4-20
Identification	5	9-30

For the thermal targets, the temperature difference may be expressed as the difference between the temperature of the bar and the temperature of the background. Subsequently, the objective is to construct the patterns so they will have temperature differences nearly equivalent to the specified contrasts of the targets.

NV&EOL recommended fabricating the thermal FEBTs out of a special resistive coating material for large area heating purposes. This material conducts current when a potential difference is impressed across it. The temperature that radiates is almost a perfect black body. A carefully controlled thermal target may be designed using thermocouples/thermistors to sense the temperature difference between the background and the thermal material layer. Utilizing a controller designed using modern solid state electronics and feedback control system techniques, a target may be constructed to render a constant thermal signature under a variety of changing ambient conditions. Initial calibration using a radiometer or similar device is necessary as a thermocouple/thermistor temperature difference may not correspond to the same differential as measured by a radiometer. NV&EOL recommended the construction of FEBTs similar to Figures 2 and 3 to satisfy the requirements for the AAH program.

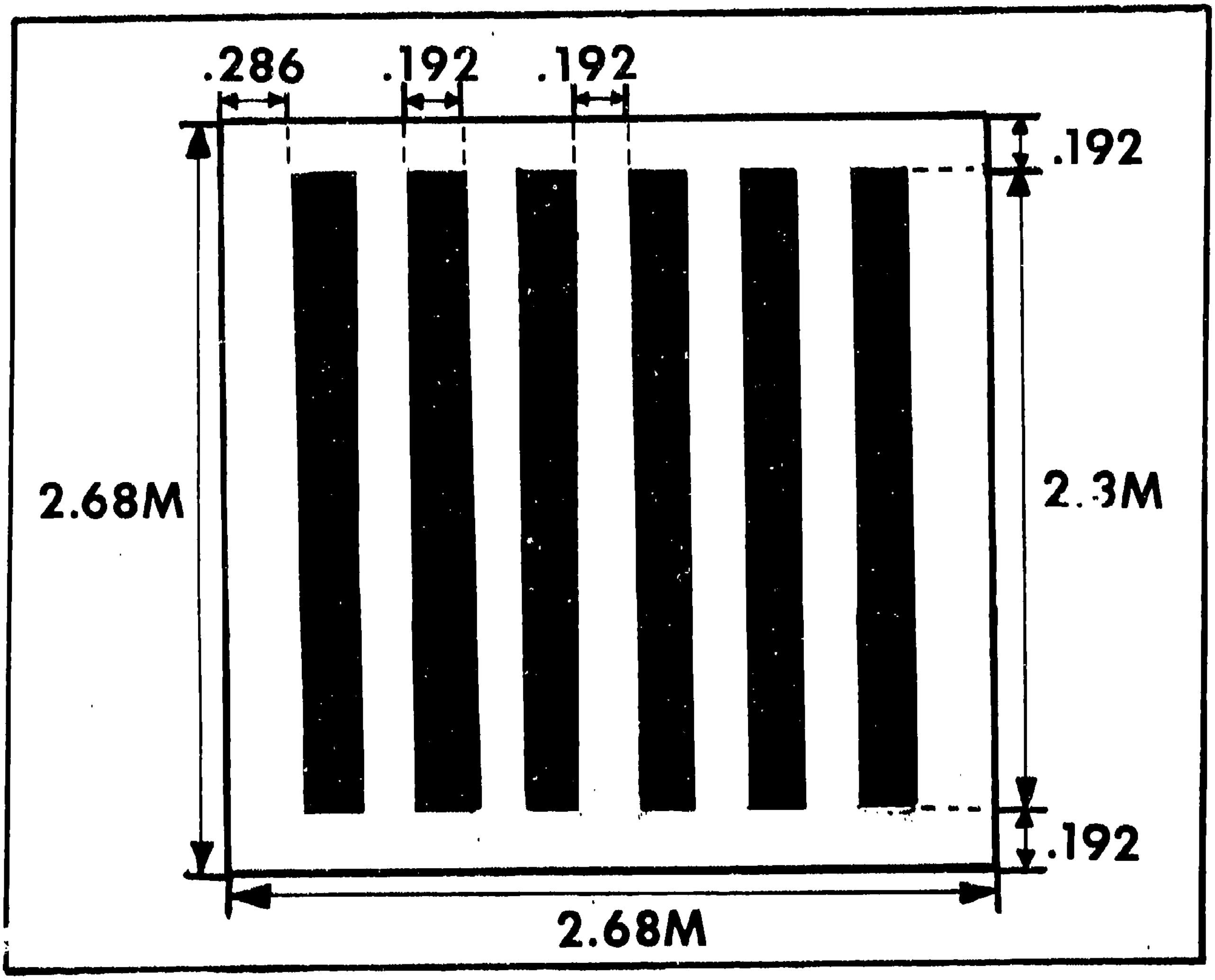


Figure 2

RECOGNITION

Field Equivalent Bar Target

(FEBT)

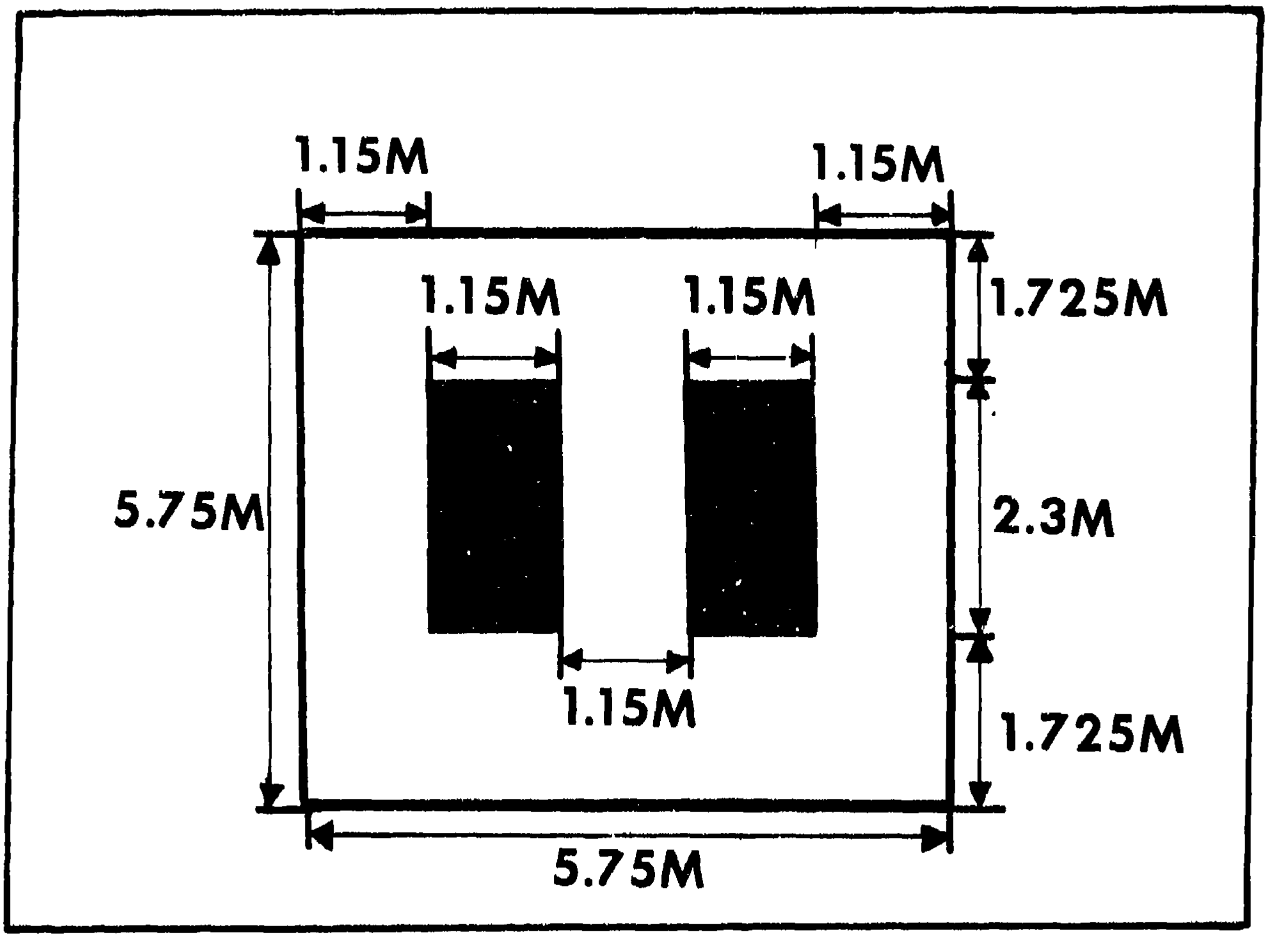


Figure 3

DETECTION
Field Equivalent Bar Target
(FEBT)

3.2.2 DESIGN OF THE FIELD EQUIVALENT BAR TARGETS

3.2.2.1 SYSTEM DESCRIPTION (Reference 4)

The Field Equivalent Bar Target (FEBT) system consists of a series of three separate controllable thermal signature targets for field test applications:

a. The Recognition FEBT--FEBT-1 (Figure 4) is composed of six heated bars, each of which is approximately 0.19 meters wide by 2.3 meters long. Each bar is separated by a background of the same dimensions. The pattern is centered in a board of approximately 2.7 meters by 2.7 meters.

b. The Detection FEBT--FEBT-2 (Figure 5) is composed of two heated bars, each of which is approximately 1.15 meters wide by 2.3 meters long. The bars are separated by a background of the same dimensions as one of the bars. The pattern is centered in a board of approximately 5.75 meters by 5.75 meters.

c. The Laser Scoring Board (Aimpoint Cross)--FEBT-3 (Figure 6) is composed of four heated squares, each of which is approximately one meter by one meter, separated by an approximately 0.2 meter wide field so as to form a cruciform when positioned upon a background.

The FEBTs are composed of a basic heater module mounted on a basic frame within a background, a control unit, and a power unit. The interface and operation of each system is quite similar.

FEBT-1 and FEBT-2 use the same configuration of heater modules which includes twelve individual heater panel elements. A thermistor is bonded to each heater panel element and the composite module is terminated to a single connector. The heater panel modules for FEBT-1 and FEBT-2 are mechanically and electrically interchangeable. The panel modules for FEBT-3 are also composed of twelve individual panels and thermistors and are electrically compatible with the other modules. However, the mechanical configuration is unique to FEBT-3.

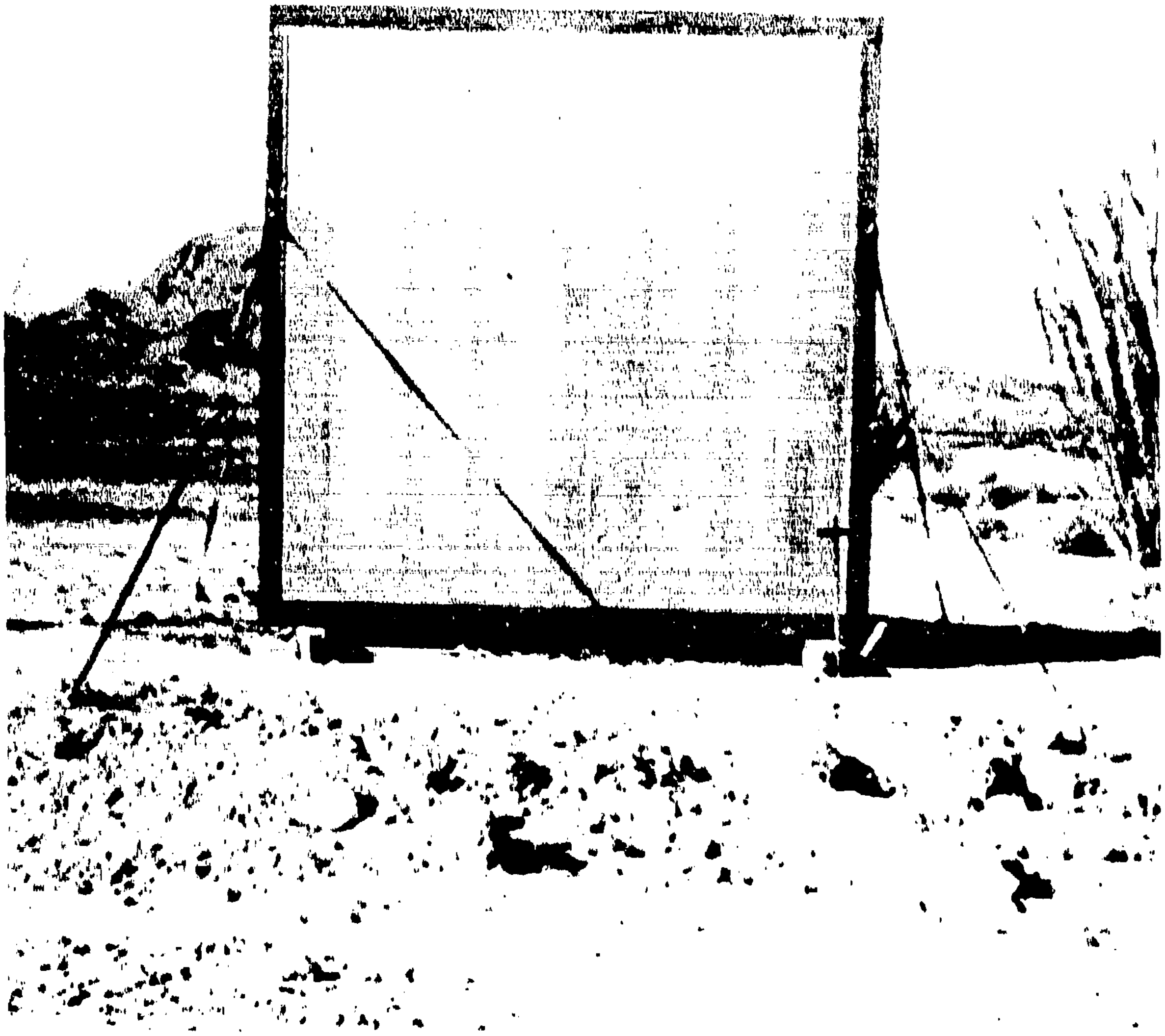


Figure 4

RECOGNITION
Field Equivalent Bar Target

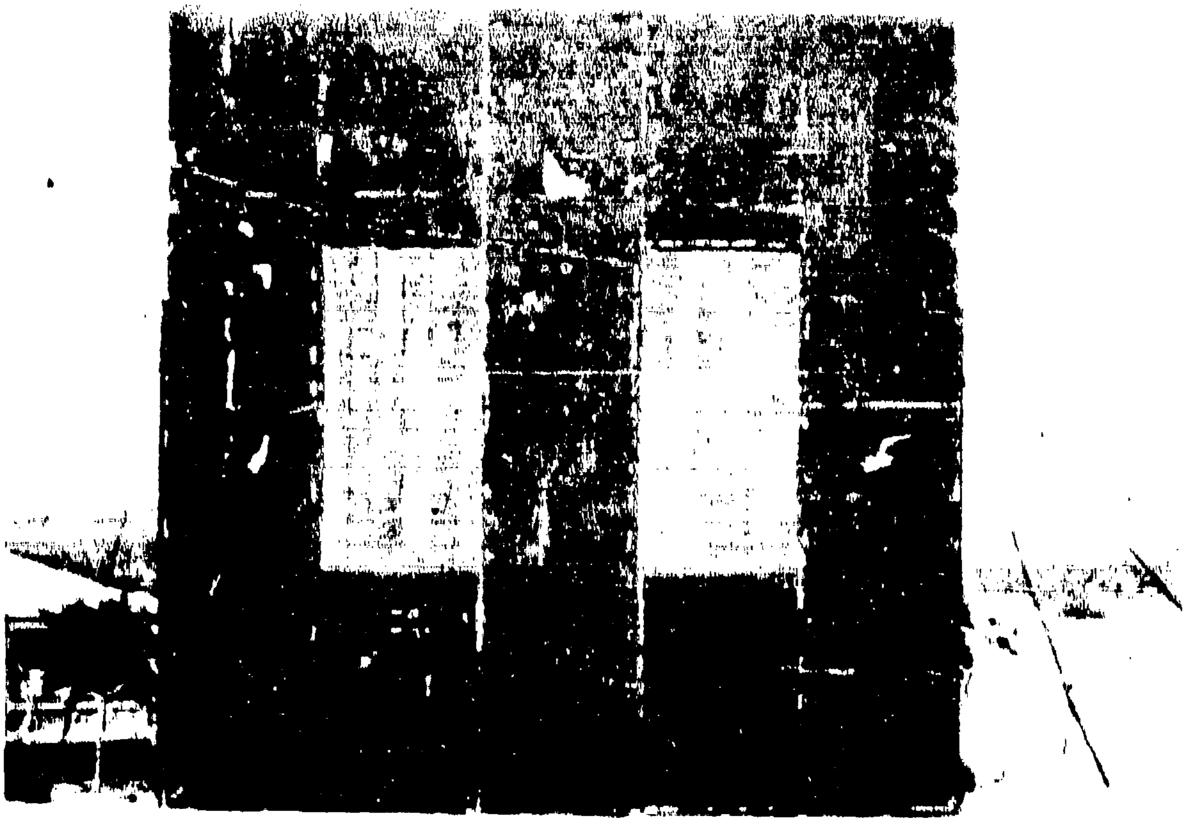


Figure 5

DETECTION
Field Equivalent Bar Target

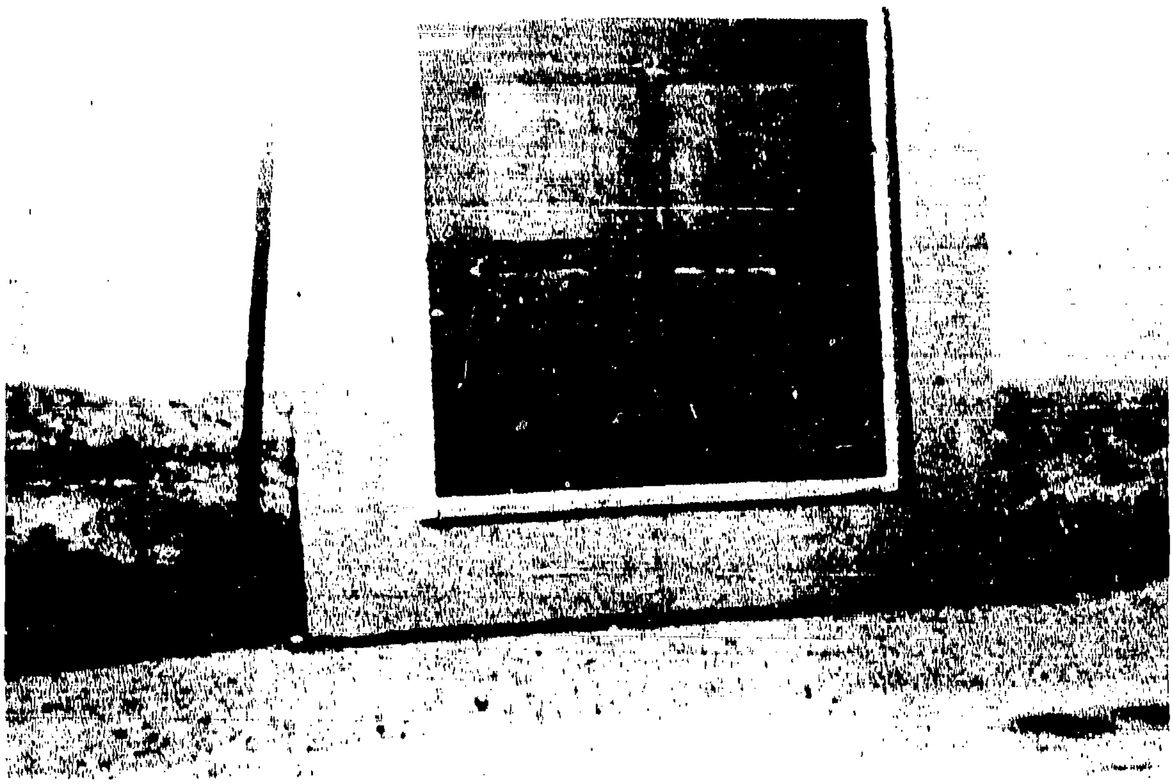


Figure 6

LASER SCORING
Field Equivalent Bar Target

A control unit (Figure 7) houses the controller cards and master controller card for each system. The controller card includes twelve temperature controllers and controls one heater panel module. A master card establishes the ambient reference, average ambient control signals, and set point control circuitry. Also included in the control unit is a set point selector switch. The configuration of the master card is unique to each FEBT while the controller cards are interchangeable for all the FEBTs. An FEBT control unit requires the master card and one controller card for each heater module (twelve panel elements). FEBT-1 has six controllers while FEBT-2 and FEBT-3 each have twelve.

Each system has a separate power unit (Figure 8) which includes DC power supplies for heater current and a separate supply for the controller output state base drive. Each system has a single thermistor located on the structure to establish the ambient temperature reference point. Additional thermistors are located on the structure adjacent to each heated area of the FEBT to establish an ambient reference for control. Four thermistors surround each active area for each target.

Structurally, the overall width of the FEBT-1 Recognition target is 2.68 meters with a height of 2.68 meters. The FEBT-2 Detection target incorporates a width and height of 5.75 meters respectively. The Laser Scoring Board, provided as a 3.3 meter by 3.3 meter insert, was mounted against a standard 20 foot square plywood-faced range target. As delivered, the stand-alone recognition and detection targets provided a wooden structure, balanced on support struts, secured via tow lines connected to trailer tie downs to provide structural integrity against wind loading. The structural frame provides a series of points to which the actual target backing is secured. Wind loads are thereby transferred to the frame for both front and rear loads.

Frontal wind loads are transferred to the frame by applying a compressive load to the target backing material and the thermal panels themselves. Winds against the rear surface apply an undesirable tensile load to the panels and backing material.

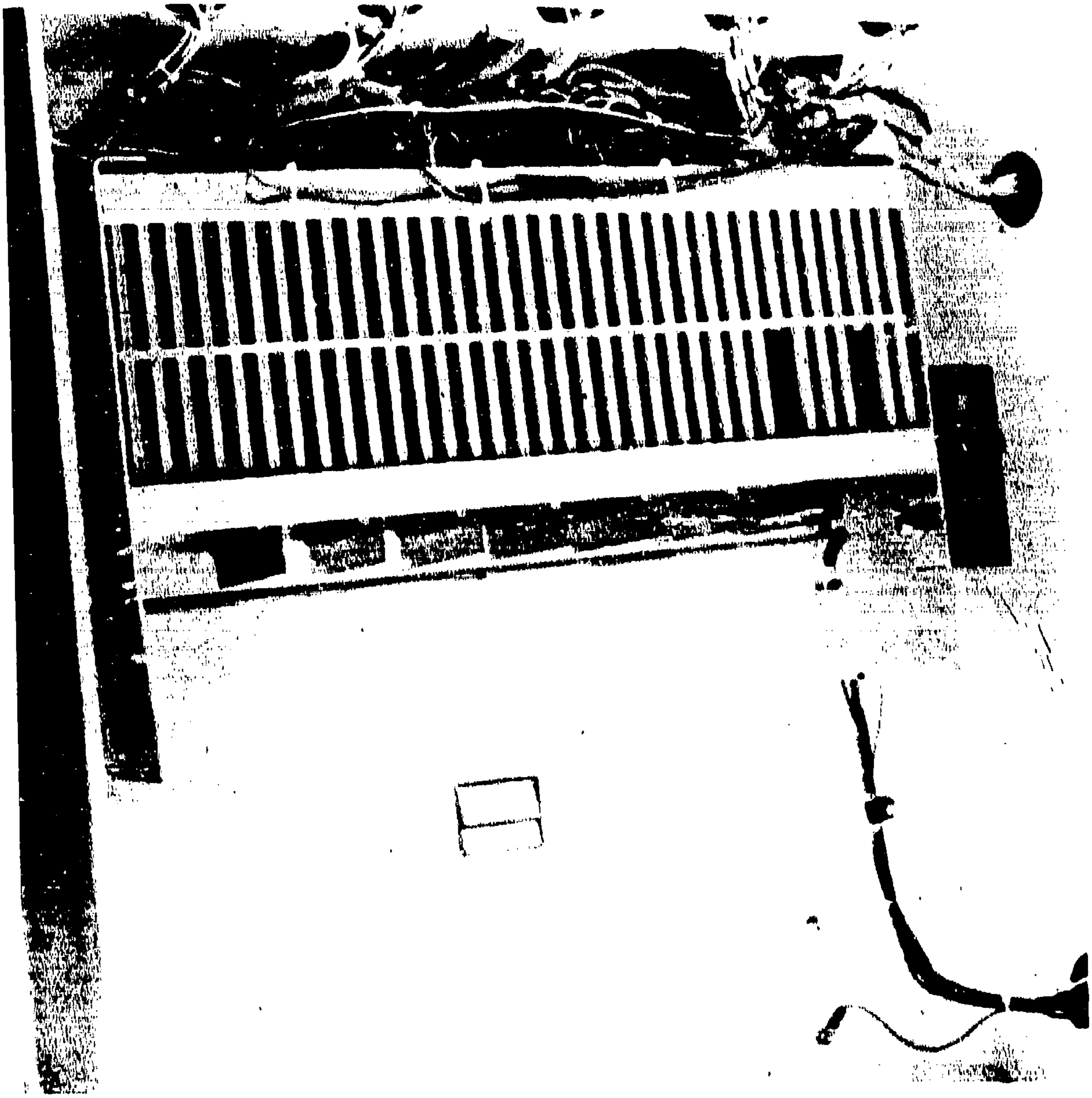


Figure 7

FIELD EQUIVALENT
BAR TARGET BOARD

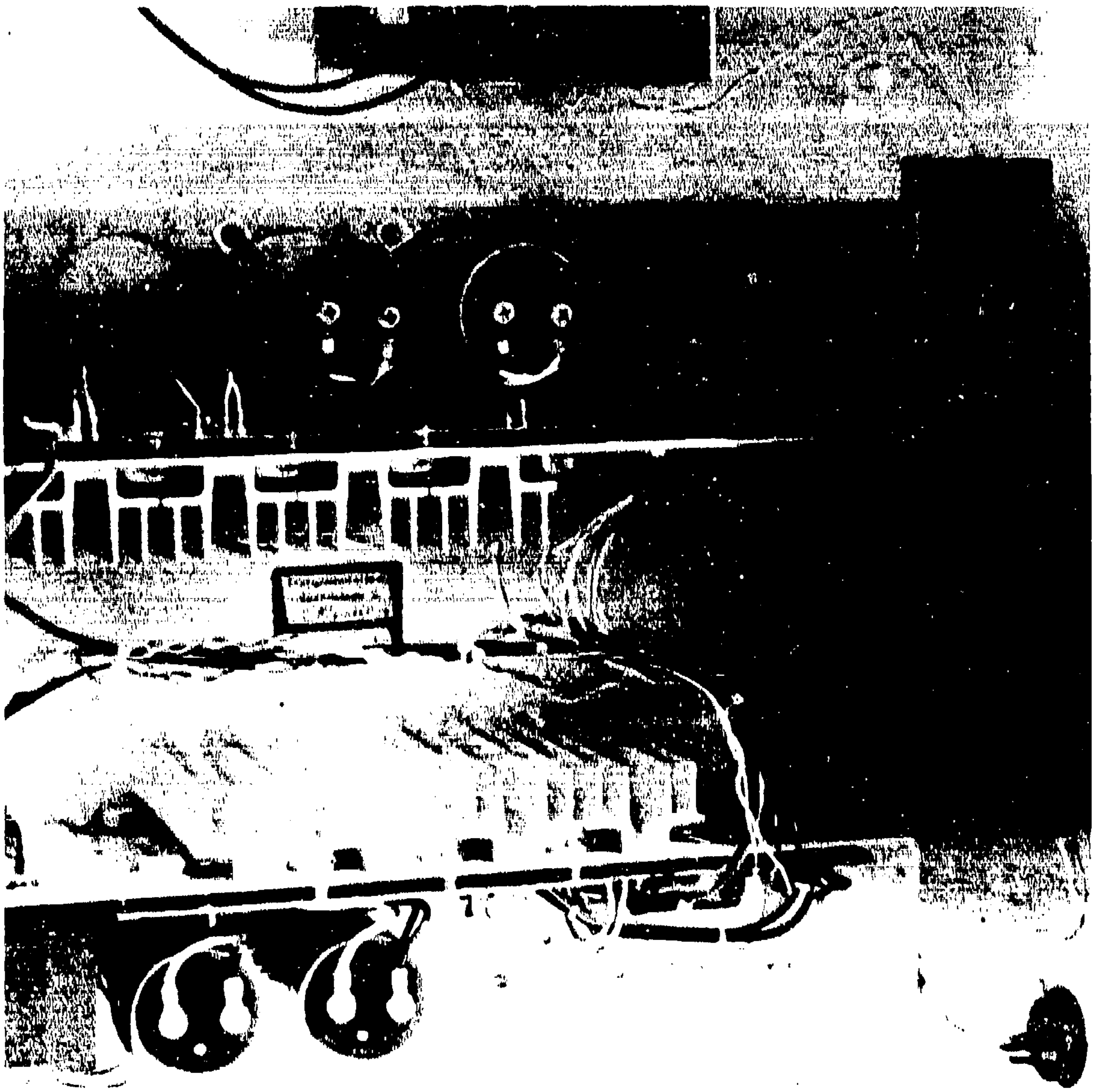


Figure 8

FIELD EQUIVALENT BAR TARGET POWER SUPPLY UNIT

The thermal signature is generated by applying a DC potential difference across a proprietary conductive film, ENERGY KOTE (Reg. Trademark), deposited on an insulative backing material. Individual elements are constructed for the Detection and Recognition targets 0.19 meter by 0.19 meter with a bus bar along each opposing side and a thermistor bonded to the geometric center of the square element to measure the absolute temperature of the element (Figure 9). The Laser Scoring Board utilizes a 0.17 meter by 0.17 meter element. Each module of FEBT-1 and FEBT-2 is constructed of panels of twelve by one elements. FEBT-3 modules are constructed of panels of six by two elements. The modules are thermally insulated from the background.

The background provides the definition of system "ambient". This background is thermally coupled to the basic structure and is decoupled from the heating film. The thermal mass of the structure is such that although gradients will exist, significant temperature changes are not readily effected in the structure because temperature excursions are integrated over the "ambient" area. Multiple temperatures are sensed on the background and an average background temperature immediately adjacent to the control surface involved is defined as ambient. The individual elements are controlled against that ambient.

Because the heating film deposition is insulated from ambient to control heat loss, a variable rate in thermal control exists. The heat up time of the target is quite short because the film is of a low thermal mass and is decoupled thermally by an air gap. No active cooling is provided and, therefore, the heat loss must be through the insulation and surface of the elements.

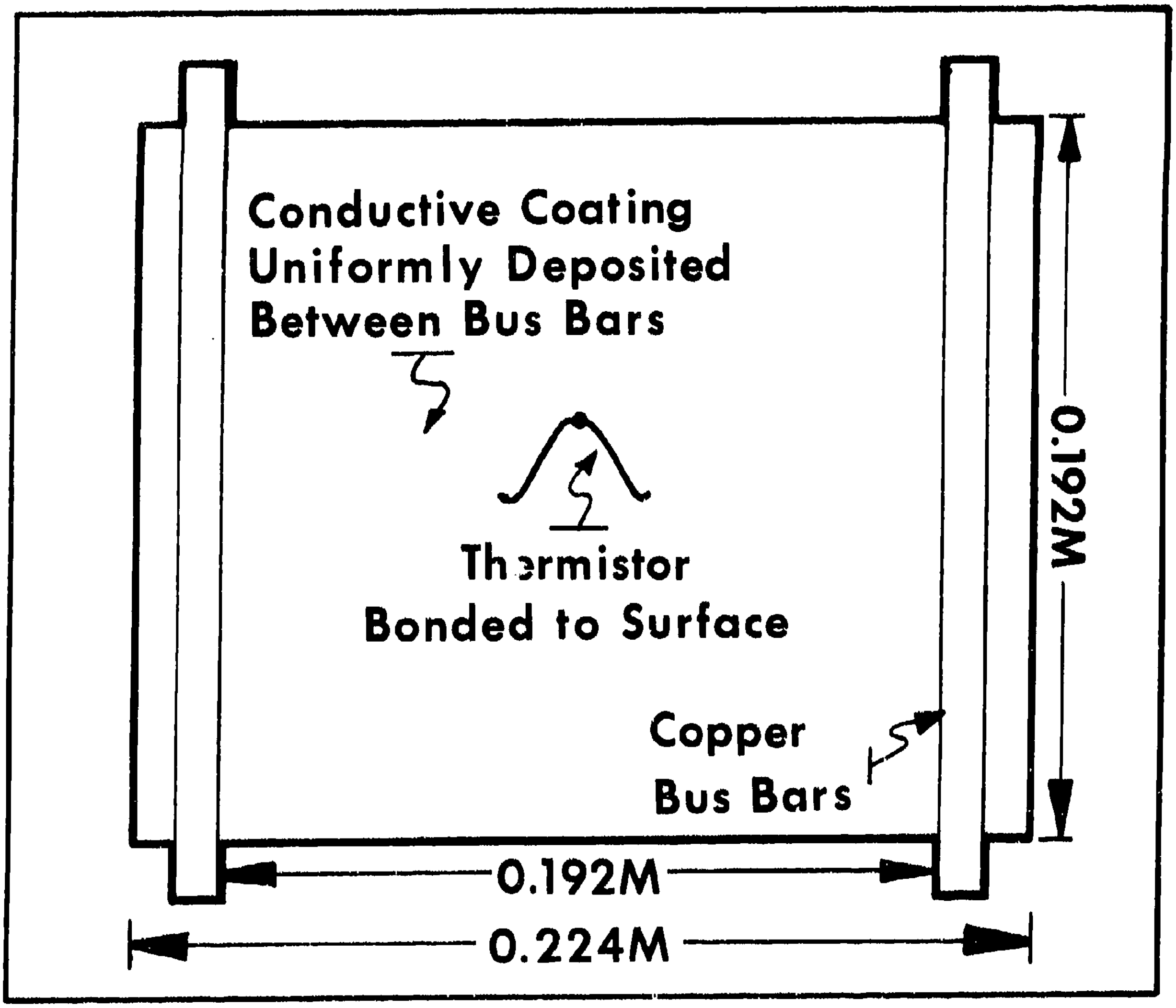


Figure 9

BASIC HEATING ELEMENT

Each panel module controls to a temperature established above the average ambient. Therefore, the panels are at approximately the same temperature. This may not be the case for the background plate as gradients may exist over the surface. A given panel element may therefore be at a differential temperature other than a selected value above the background plate immediately adjacent to it, but it controls to the average plate temperature. The selection of the transducer locations on the integrating background plate (See P. 19) and the number of transducers greatly influences the quantitative measurement of the "average ambient". As the plate average changes, the controllers, and hence the heaters track that change. The heaters are non-synchronous, and will cycle on and off as their individual sensors and controllers dictate. The rate and reset control, inherent in the design, will filter exaggerated temperature due to the asynchronous operation and differences in thermal paths due to contruction and material differences. Because the panel element only applies heat, cool-down control is determined by the response time of the structure, by the background plate, and by the insulation scheme used in the heater panels.

Table 3--Set Points Selected for the FEBT System

Set Point	Temperature Differential
0	OFF
1	+1.25
2	+3.0
3	+5.0
4	+7.5
5	+10.0

3.2.2.2 THEORY OF OPERATIONS (Reference 4)

A set point (Table 3) is selected by the selector switch which establishes a reference voltage to the summing network in the controllers. The set point voltage is varied as a function of the actual ambient temperature through a feedback amplifier to compensate for the nonlinearity in the thermistors. Four thermistors are connected in parallel to obtain an average of the temperature adjacent to the panel and this signal is similarly applied to the summing network. A trim resistor potentiometer adjusts the summing network for variations in the sensing thermistor. The resultant output of the summing junction provides a reference to the control amplifier. A thermistor mounted on the heater panel element provides the other input to the amplifier (Figure 10). When the panel temperature is below the reference temperature, the input voltage will be above the reference and hence saturate the amplifier, turning on the heater via the output transistor. Once the panel temperature stabilizes, the voltage across the thermistor is reduced, shutting off the control transistor.

The heater panel modules are configured to be interchangeable for the FEBT-1 Recognition and FEBT-2 Detection targets. Each module is composed of twelve discrete heater panel elements composing a bar approximately 0.19 meters by 2.3 meters. Each panel element is monitored by a thermistor for control. The bar assemblies are harnessed to a connector which mates with the connector located on the control unit. Any heater module can interconnect with any controller connector on the control unit and similarly any controller can control any heater panel. For the FEBT-3 Laser Scoring Board, the basic heater module is composed of twelve heater panel elements arranged to provide a module of approximately 0.33 meters by one meter.

Formed metal pans provide the structure and "ambient" background for the overall target. Because the active heated area is controlled against the "average ambient temperature" immediately adjacent to the control surface, selected background panels are instrumented with thermistors. This instrumentation is different for each target because the active area configurations differ. For the FEBT-1 Recognition target, the background adjacent to each of the six active modules is instrumented. The end pans have two thermistors while those pans between active modules have four thermistors. The thermistors are grouped in fours to measure the temperature adjacent to the active area. The thermistors for each pan are terminated to a Winchester Connector and connected via a harness from those connectors to the thermistor input connector located on the control unit. A single thermistor is located on a pan to measure the actual temperature of the environment and it is also included in this harness.

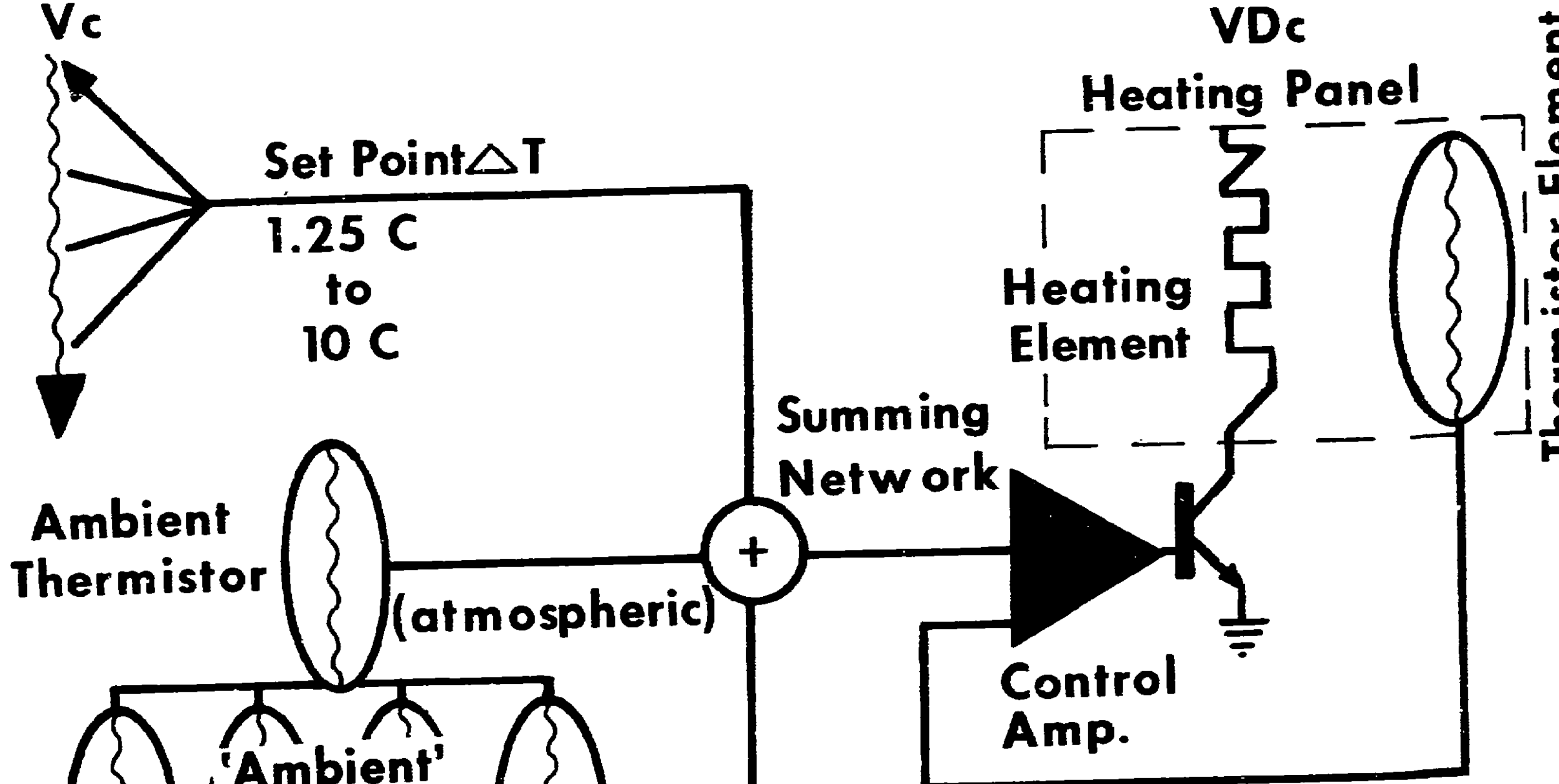


Figure 10
CONTROLLER
CONCEPT

For the FEBT-2 Detection target, the active areas are a grouping of six heater modules that form two active bars. The background thermistors are configured to measure those two areas. Thus, four thermistors surround each area.

The FEBT-3 Laser Scoring Board has four active areas each of which is surrounded by four thermistors.

The control units (Figure 7) house the control electronics and provide an interface junction box for the heater panels and thermistor harnessing. Each control unit contains a printed circuit board card frame to contain the controller cards and a master card. The card frame is wired to the interface connectors for the panels and also to a test connector for each panel. The test connector provides a test point for each thermistor which is located on the heater panel elements and it will provide a point to measure the voltage which appears at the control amplifier. By monitoring this voltage, the panel temperature can be obtained and also a determination of temperature control can be established. The wiring for all controller cards and test connectors is identical for all three targets in the system, with the only difference being that FEBT-1 employs six controllers, six panel interface connectors, and six test connectors; while FEBT-2 and FEBT-3 use twelve controllers, twelve interface connectors, and twelve test connectors. Because the interface wiring to any controller board is the same for any of the FEBTs, and because the controller boards are similarly identical, any controller card can be used for any panel for any of the FEBTs. It should be noted, however, that the control may vary as the controllers are interchanged due to variations in the trim. These changes should be very slight and not significant to systems operations; however, the phenomenon should be recognized.

The master cards are unique to each system. The number of average temperatures for each target differs and, therefore, the number of amplifiers used is different. Also, trim adjustment to the ambient reference amplifiers may vary from master card to master card. An average ambient for each controlled module is fed to the controller card summing junction. The ambient signal is associated with the panel under control. In the case of FEBT-1, each of the six controllers has a separate ambient from the master card. For FEBT-2, which controls only two areas, only two references are provided and the controller inputs are bused in groups of six each. For FEBT-3, four active areas are required, thus four reference inputs are used while the controller inputs are bused in groups of three.

Each FEBT system includes a separate power unit (Figure 8) which houses the DC power supplies for heater power and transistor drive. One power supply in each unit is designated as a 10 V power supply and it provides the base current drive for the controller output transistors and is the supply for the operational amplifiers. The power supplies designated as +28 V provide the actual heater power. The configuration of FEBT-1 power unit is slightly different from that of FEBT-2 or FEBT-3. Two +28 V supplies are used with FEBT-1 and are bussed separately to groups of three bars. FEBT-2 and FEBT-3 employ three +28 V power supplies, each of which is bussed to four bars. A single cable interconnects the power unit and the control unit. The main power ON/OFF switch and fusing are in the power unit.

3.3 SYSTEM UTILIZATION

3.3.1 DETECTION/RECOGNITION TARGETS

The detection/recognition targets were utilized in the classical manner described in section 3.2.1. The aircraft flew along a predetermined flight path towards the target. The observer announced "detection" when he could resolve the two-bar target and "recognition" when he could resolve the six-bar target. Range to target, ambient conditions, and other parameters are factored into an evaluation model of system effectiveness. Cockpit video corroborated the observer's perceptions. The whole evaluation system is predicated upon visual acuity and the human ability to perceive; and, as such, it presents many biasing factors.

3.3.2 LASER SCORING BOARD (AIMPOINT CROSS)

The Laser Scoring Board was utilized precisely as its name implies. A near infrared vidicon with a 1.06 micrometer sensitivity was used to detect the laser pulses striking the target. A notch filter of 100 Angstroms about 1.06 micrometers was used to sharpen the test data about the wavelength of interest. Local video instrumentation was set up to display and record the data.

Video tapes were brought back to the USAYPG Range Operations Center (ROC) for processing under the supervision of the Electro-Optics Unit of the Data Acquisition and Reduction Branch. Each tape was processed for time base correction and loaded onto video disc in 10 second increments.

As each new laser pulse was played back from video disc, a Quantex DS-20 was used to frame grab and store the image. An HP-1000 with appropriate software reduced the data.

The search window was established to be the target size. The "recorded brightness" thresholds, which are proportional to energy densities, were set at 10 and 100% to capture the area of the laser spot for which the recorded brightness is ≥10% of the peak recorded brightness. Minimum brightness was set at the target ambient and the target birghtness peak was established as 100%. This was done to eliminate digitization on target peaks, which occurs when average values are used for maximums and minimums. The proportion of the recorded brightness corresponding to energy is highly dependent upon the dynamic range of the camera.

The data, as acquired, was then transferred to a digital array and the geometric centroid was calculated in cartesian coordinates (X,Y). The centroid was generated relative to the actual center of the target (herein designated Xo,Yo). Also, plots of X versus time (X,t) and Y versus time (Y,t)--beam jitter--were generated. Further analysis provided histograms of the percent of energy falling in a specific geometric region of the target.

Additional analysis of the data acquired from the Laser Scoring Board was performed by the U.S. Army Missile Command (MICOM), Huntsville, AL, who performed Power Spectral Density and Phase Angle Analyses, in addition to other parametric investigations.

4. COST EFFECTIVENESS

The objective of this development and acquisition project was to provide, at low cost, an initial set of unique and specialized thermal targets required for the testing of the fire control systems in modern airborne and ground-based armament systems. In particular, the testing of the fire control system of the YAH-64, Advanced Attack Helicopter (AAH), TECOM Project Number 4-AI-100-AAH-004, was to be accomplished.

The measure of the cost effectiveness of the system is essentially qualitative in nature as there are no standards previously developed with which the costs may be compared (Appendix C). These targets were developed to provide a unique capability, not presently in existence at any test and evaluation facility. Previously, active element, precision controlled thermal bar targets were a laboratory instrument only. In this respect, the development of these targets significantly advanced the state-of-the-art of field testing thermal imaging systems.

The utility of these targets is not limited solely to the testing of the AAH fire control system. All thermal sight test and evaluation of modern airborne and direct-fire weapon systems can benefit from this development effort. As the threat reaches new levels of sophistication in its night-fighting capability, test and evaluation of U.S. and Allied weapon systems incorporating thermal imaging systems will require a consistent set of field test thermal target standards. This development is a first step; and as such, should be evaluated as a potential test standard against which future developments can be measured.

Alternative design schemes were not costed out. They were assessed as being unacceptable due to size, weight, complexity, lack of modularity, etc.

However, the objective of providing sufficient thermal realism at a reasonable cost to adequately test specified parameters of airborne and ground-based fire control systems has been met. Prior to the acquisition of this ability, no TECOM facility maintained a field testing capability to simulate thermal realism. Earlier field testing consisted of the use of real scene objects and a subjective evaluation of the ability of the system under test to resolve the target. Consequently, future cost benefits will accrue in the utilization of these targets in the test and evaluation of advanced weapon systems incorporating thermal imaging sights.

5. CONCLUSIONS

5.1 Thermal design goals of the acquisition were met, within acceptable limits (Appendix B).

5.2 State-of-the-art in the field testing of weapon systems incorporating thermal imaging sights has been advanced.

5.3 The system provides cost benefits in the test and evaluation of weapon systems incorporating thermal imaging sights.

6. RECOMMENDATIONS

6.1 The FEBT system be evaluated by the TECOM community for consideration as a potential test standard.

6.2 The FEBT system was a successful research and development effort resulting in system prototypes. These prototypical thermal targets were not designed to take the severe environment imposed on them by permanent location on the Cibola Instrumented Range. High winds in excess of 45 mph carrying abrasive sand have pelted and damaged the original target structures. Extensive in-house structural modification has been necessary to supplement the original target frame to withstand the high winds. The dry Yuma climate, as well as continual wind-induced flexure, caused considerable damage to the thermal panels; i.e., glued seams parted and epoxied thermistors separated from the measurement surface of interest.

The prototype FEBT system has demonstrated the cost-effectiveness of the design approach; however, the fragility of the FEBT system presents obstacles to full utilization of the FEBT potential: moving the targets from one point to another on the range, readily reorienting the bar pattern 45 or 90 degrees, and utilization of a thermal moving target for dynamic field performance measurement.

It is therefore recommended that a series of sets of environmentally "hardened" targets be acquired for continued thermal sight testing. One series should be designed to permit mounting on a remote controlled target carrier to provide a moving thermal target capability. (The constraints imposed by meeting moving target requirements may require some degradation in characteristics (e.g., reduced size) from the semi-fixed set.)

APPENDIX A

References

References:

1. Wolfe, William L., Test Targets for Visible, Near Infrared and Infrared Imaging Devices, Infrared Inc., January 1979. (Contract DAAD01-78-M-1557)

2. Goodell, John B. et al, The Fundamentals of Thermal Imaging Systems, Naval Research Laboratory Report NRL 8311, 10 May 1979. (AD A073 763)

3. Johnson, John, "Analysis of Image Forming Systems", Proceedings of Image Intensifier Symposium, 6-7 Oct 1958.

4. ITE Inc., Field Equivalent Bar Target Systems Operation and Maintenance Manual, Prepared for Contract DAAD01-79-C-0037 by ITE Inc., Beltsville, MD, for the TVI Corporation, Kensington, MD, 1980.

5. Army Materiel Command Pamphlet AMCP 706-127, Engineering Design Handbook-Infrared Military Systems, Part One, 21 April 1971.

6. Wolfe, William L. (ed.), Handbook of Military Infrared Technology, Office of Naval Research, Department of Navy, Washington, DC, 1965.

7. Rosell, Frederick A. and Willson, Robert H., Performance Synthesis (Electro-Optical Sensors), Air Force Avionics Laboratory, AFAL-TR-72-279, August 1972. (AD 905 291)

APPENDIX B

Acceptance Test Data

DEPARTMENT OF THE ARMY
ARMY NIGHT VISION AND ELECTRO-OPTICS LABORATORY
FORT BELVOIR, VIRGINIA 22060

DELNV-VI

01 JUL 1980

SUBJECT: Night Vision and Electro-Optics Laboratory Support of Field Equivalant Bar Targets (Contract DAAD01-79-C-0037)

Commander
US Army Yuma Proving Ground
ATTN: STEYP-TD (Mr. R.H. Miller)
Yuma, AZ 85364

1. Reference, Yuma Proving Ground Work Directive PRON K1-9-R0013-01-L5-CJ dated 1 Aug 79.

2. Reference telephone conversation between Mr. Moulton, this office, and Mr. Miller, YPG, 18 Jun 80, SAB.

3. In support of the subject contract, the Night Vision and Electro-Optics Laboratory conducted a series of preliminary tests on the thermal target boards per the work directive, Reference 1. The results of these tests are the subject of the report entitled, "Preliminary Tests of Field Equivalant Bar Targets No's 2 & 3" (Incl 1). Copies of this report were presented to Mr. E. Scott at Yuma Proving Ground on 3 Dec 79. This report accurately describes the capability of the thermal target boards with regard to the capability to attain and maintain a pre-selected ΔT. Uniformity of temperature across the target boards and conditions that affect set point uniformity are also addressed in the inclosed report. A summary of these technical parameters as determined by NV&EOL is provided in the table below.

Design Set Point $\Delta T^{o}C$ $\pm 0.2^{o}C$	Measured $\Delta T^{o}C$ FETB 2	Measured $\Delta T^{o}C$ FETB 3
1.25	1.59	1.31
3.0	2.98	2.63
5.0	4.57	4.53
7.5	6.88	6.46
10.0	7.30	7.32

0 1 JUL 1980

DELNV-VI
SUBJECT: Night Vision and Electro-Optics Laboratory Support of Field Equivalant Bar Targets (Contract DAAD01-79-C-0037)

Specific shortcomings observed by NV&EOL during preliminary testing are discrepancies between the design goal set point tolerances and those actually measured. The discrepancies were greater at the higher (7.5°C and 10.0°C) set points, whereas the measured ΔT was within about 0.4°C for most of the lower set points. The importance of maintaining the air cup material in close proximity to the active panel surface in order to preview large uniformity differences was noted.

4. In addition to the data described in the inclosed report, an analysis has been conducted by this laboratory of the results of field MRT measured during the recent AAH test using the FETB's as it compares to the laboratory measured MRT. This analysis indicates that field obtained MRT using the thermal target boards was approximately 40% of the MRT at high spatial frequencies over that obtained in the laboratory. This is considered a significant finding in that it demonstrates a clear degradation of sensor performance when measured on the normal operational platform. This finding is not unusual when compared to past experiments, but does indicate the usefulness of a field target board.

5. Although the current target boards have a fragility that excludes continued field usage (as discussed with R. Moulton, Reference 2), a field target board concept clearly provides a capability to access the operational MRT of FLIR sensors that can be obtained no other way. It is suggested that YPG consider a follow-on hardened MRT target board if continued FLIR testing is envisioned. Please advise if we can be of further assistance in this endeavor.

1 Incl
as

Joseph R. Moulton

JOSEPH R. MOULTON
Director, Visionics Division
Night Vision and Electro-Optics Laboratory

COPY, AS AMENDED

PRELIMINARY TESTS OF FIELD EQUIVALANT BAR TARGETS NO's 2 & 3

INTRODUCTION:

The enclosed report describes the results of preliminary tests conducted on the Field Equivalent Bar Targets #'s 2 and 3 at Night Vision and Electro-Optics Laboratory, Ft Belvoir, VA.

The primary measurement device was the NV&EOL Thermoscope manufactured by Texas Instruments, Inc. A description of this device and the measurement and data analysis techniques are included as Appendix I. Also included in Appendix I are representative photographs of the thermoscope imagery of both FEBT 2 and 3.

Final acceptance testing will be performed by NV&EOL personnel at Yuma Proving Grounds.

An AGA thermoscope will be used to determine:

1. The target boards are functioning as observed at NV&EOL (FEBT 2 and 3).
2. The set point temperatures of FEBT 1, which was delivered to YPG prior to the NV&EOL preliminary tests.

A PRT-5 radiometer will be used to determine approximate Δt of each of the FEBT's (PRT-5 is accurate to $\simeq 0.5^{\circ}C$).

CONCLUSIONS:

The design requirement set point Δt's were not met in most cases within the desired $\pm 0.2^{\circ}C$.

The table below describes the desired set point Δt, the measured Δt, and the deviation from the desired set point Δt for FEBT 2.

DESIRED $\Delta t \pm 0.2^{o}C$	AVERAGE MEASURED Δt	^{o}C FROM SET Point
1.25	1.59	+0.34
3.0	2.98	-0.02
5.0	4.57	-0.43
7.5	6.88	-0.62
10.0	7.30	-2.70

The discrepancies noted above are not considered by NV&EOL to impact the usefulness of the FEBT-2 as a precision measurement device.

Most, if not all, of the AAH measurements are expected to be conducted at the lower (1.25°C and 3.0°C Δt) set point.

The 1.25°C set point is only +0.14°C out of specification and the 3.0°C t set point is well within the 0.2°C tolerance. The uniformity was very good at all set points.

The slight discrepancy from the tolerance of the 1.25°C Δt set point is not considered relevant. What is important is to know the precise Δt for each of the set points.

The discrepancies found at the higher set points are not considered important since they will, in all probability, not be used in the AAH TADS/PNVS fly off.

It is important, however. to know the $\Delta t/^{o}C$ of the higher set points.

The fabrication of the FEBT #3 was a "best effort." However it is obvious that this device, too, is a precision measurement device.

A similar table describes the desired vs measured data for FEBT #3. Note: The average measured Δt is for three of the four areas of FEBT #3 - see the results section for a complete explanation.

DESIRED Δt $\pm 0.2^{\circ}C$	AVERAGE MEASURED Δt	$\pm ^{\circ}C$ FROM SET POINT
1.25	1.31	+0.06
3.0	2.63	-0.37
5.0	4.53	-0.47
7.5	6.46	-1.04
10.0	7.32	-2.68

RESULTS:

Initial attempts of measuring the differential bar temperatures on 30 Oct and 1 Nov were unsuccessful due to failure of the target panel to maintain a set point. This was finally resolved on 15 Nov. When the 10K resistance in the set point voltage divider were found to be intermittently open. These were replaced but the panels still have occassional problems with either single elements or columns of elements not controlling. These difficulties were traced to bad contacts in connectors.

On 15 November a complete test of FEBT-2 was conducted, starting at the 1.25 set point... The panels were unable to reach the 7.5 set point until the current limit adjustments in the 28 VDC voltage regulators were changed. The 10 degree set point was not reachable even with these adjustments. A problem was found with an approximately five volt drop in the 28 volt return line from the controller box. This was due to inadequate gauge wires carrying the current. This was temporarily fixed with a jumper wire allowing the panels to reach the 10 degree set point.

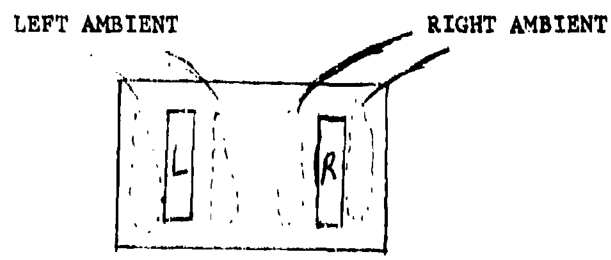
FEBT-3

These panels were run exactly the same at FEBT-2, with a series of thermistor measurements being made at each set point to insure that the panels were controlling. No problems were encountered this time except that it was noted if the air-cap is not kept pressed close to the panels, apparently temperature differences in the radiometric measurements are noticed, even though the thermistor measurements indicate that all the panels are at the same temperature.

Non-Uniformities

Large-amplitude, small-scale radiometric non-uniformities were measured across the panels. They appeared much hotter at the junctions between separate thermal squares, apparently due to an emissivity difference rather than a temperature difference. From a distance, these are hardly noticeable as illustrated by the pictures. A blow-up of the four squares in the FEBT-3 panel is included for comparison.

FEBT-2



(Air-Cap only over two bars, not over ambient panel)

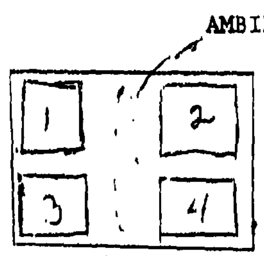
Set Point	ΔT_L	ΔT_R	Thermistor Approximation
1.25	1.58	1.60	1.78
3.0	2.91	3.05	2.9
5.0	4.31	4.83	4.7
7.5	6.99	6.77	6.75
10.0	7.05	7.55	8.4

Remarks

The only radiomatric measurement that does not appear consistent with the thermistor readings is that of the 10° set point. From the thermal images it can definitely be seen that it is hotter than the 7.5° set point; however, the temperature variance across the panels appears greater. This probably explains the discrepancy.

Only at the 5° set point (excluding 10°) was the difference between the two bar temperatures significant.

FEBT-3



(Air-Cap only over four squares, not over ambient panel)

Set Point	ΔT_1	ΔT_2	ΔT_3	ΔT_4	Thermistor Approximator
1.25	1.30	.84	1.22	1.41	1.2
3.0	2.46	2.05	2.66	2.76	2.8
5.0	4.57	3.67	4.60	4.42	4.8
7.5	6.53	5.72	6.37	6.47	6.8
10.0	7.49	6.63	7.31	7.16	7.8

Remarks

On panel square #2 the air-cap was not flat against the thermal elements. This probably accounts for the low readings. Transmission loss on the air-cap may account for the discrepancies between radiometric and thermistor measurements. The thermistor measurements are the average over a small sample of random readings.

Appendix I

Method of Radiometric Signature Measurement

The signatures in this report were measured with NV&EOL's thermoscope. The thermoscope is a 33° by 33° field of view horizontal line scan (500 lines) imaging system with reflective optics, a HgCdTe (8-12 micron) single-element detector-dewar module, and an internal controlled blackbody for temperature reference. The framing period is 4.5 seconds. As the thermoscope detector scans across the image and reference blackbody, the preamp voltage is sampled, digitized to eight bit precision and recorded on digital magnetic tape. This digitization and recording process is performed by NV&EOL's Phase I Digitizer system.

The thermoscope is calibrated immediately before the measurement exercise by determining the detector-preamp temperature-to-voltage transfer curve, the internal reference blackbody set-points, and the A/D converter transfer curve. The thermoscope Calibration Set, which includes an environmentally stable blackbody reference source, is used for this purpose. Figure B-1 illustrates a typical calibration. This data is stored on magnetic tape along with the digital images and is used in the data reduction process.

The recorded digitab tapes are later processed on the Night Vision System Simulator (NVSS) Image processing facility. As each image is read, the digital preamp values are adjusted in offset by the internal temperature reference values to DC restore the AC coupled preamp signal. Calibration data for the thermoscope's radiometric temperature-to-video signal transfer function is then applied to complete the conversion to a calibrated radiometric temperature digital image.

Each calibrated image is then processed on the interactive Image Manipulation Facility. Using the IMF, regions of each image corresponding to objects of interest are outlined. The average temperature within each region is then computed on the NVSS and used to generate the data presented herein.

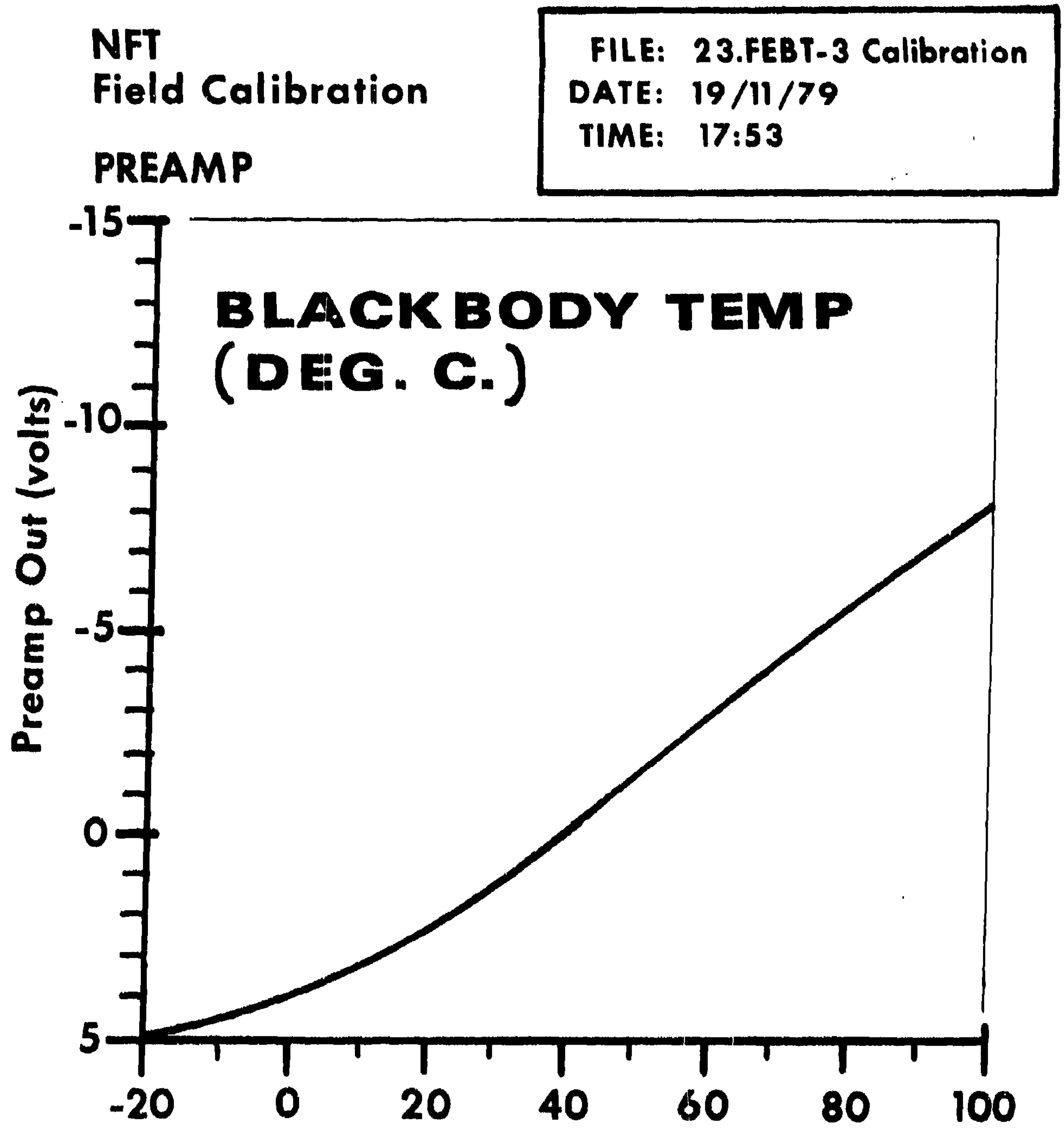


Figure B-1

(TYPICAL THERMOSCOPE CALIBRATION CURVE)

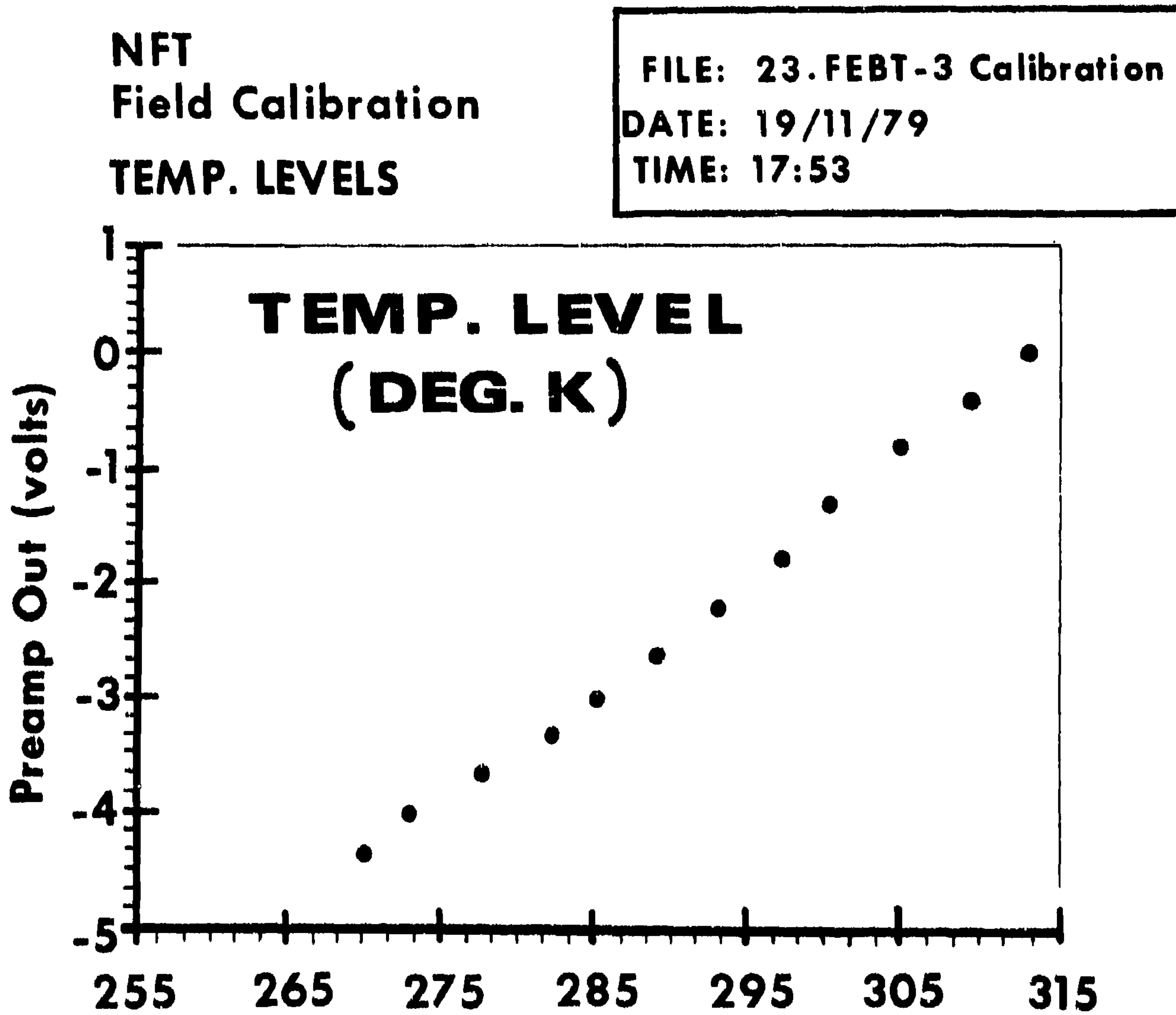


Figure B-2

(TYPICAL THERMOSCOPE CALIBRATION CURVE)

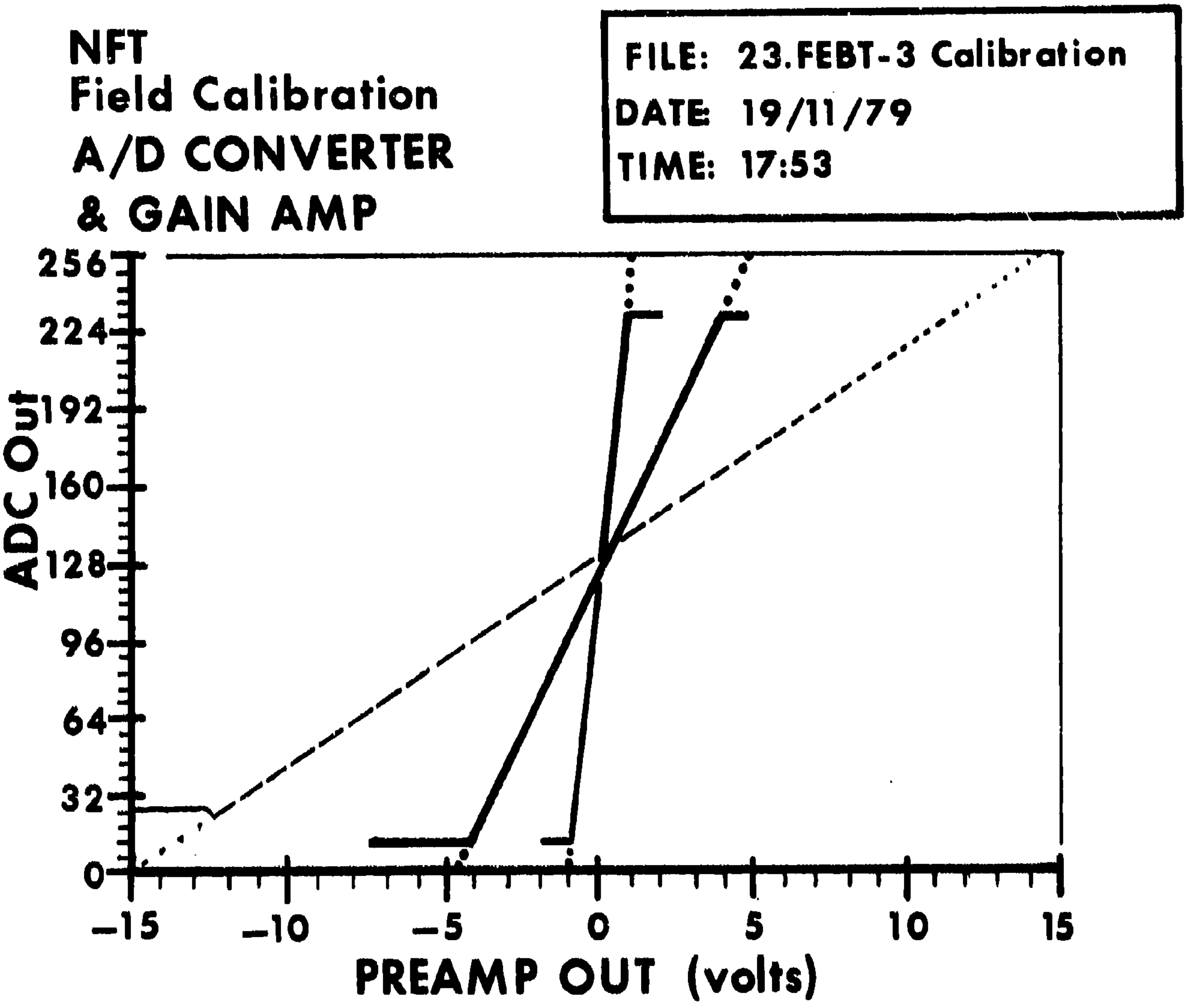


Figure B-3
(TYPICAL THERMOSCOPE
CALIBRATION CURVE)

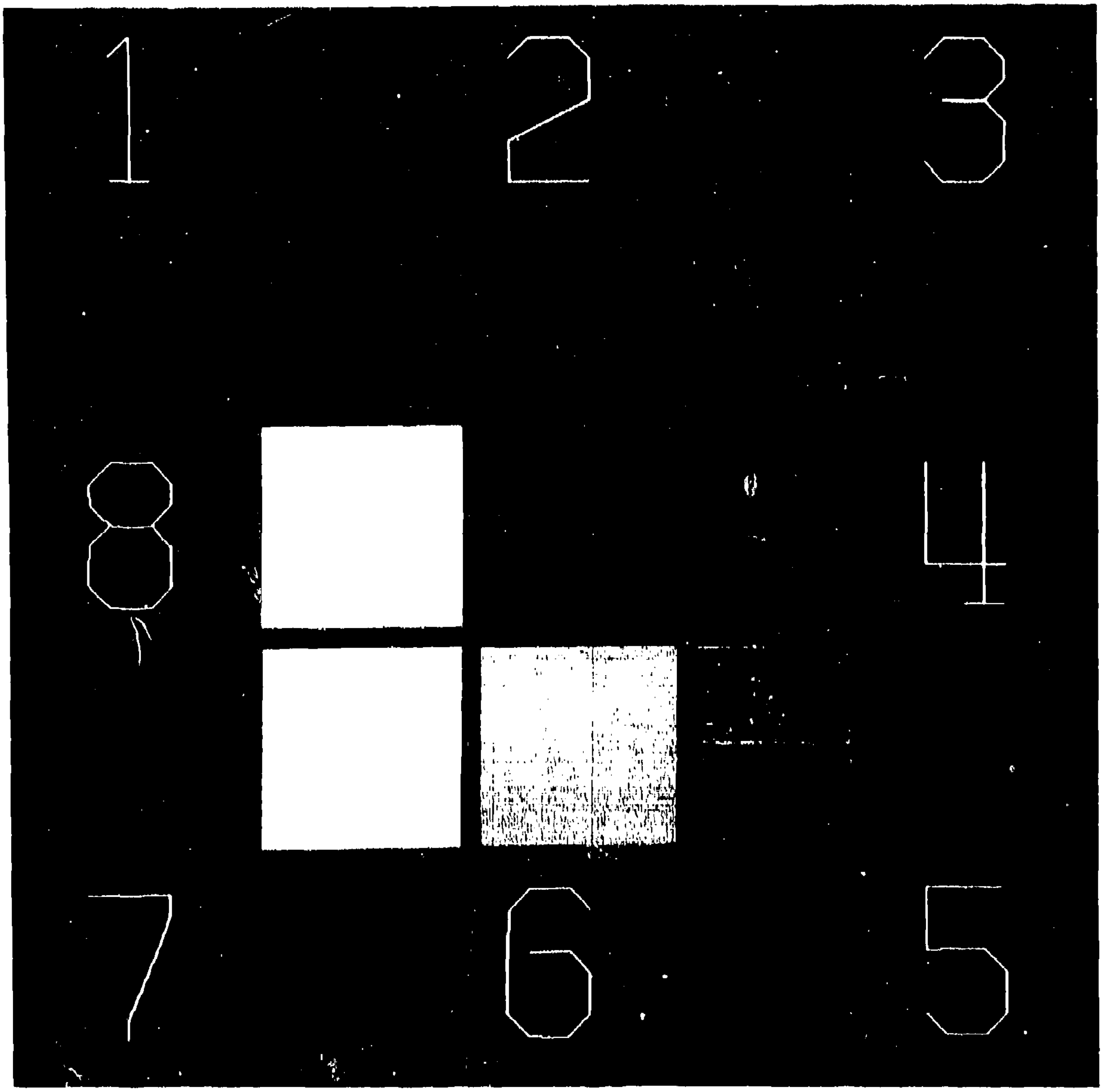


Figure B-4

GRAYSCALE FOR FILM

Note: All were recorded with

Black = 291°K Clear = 275°K

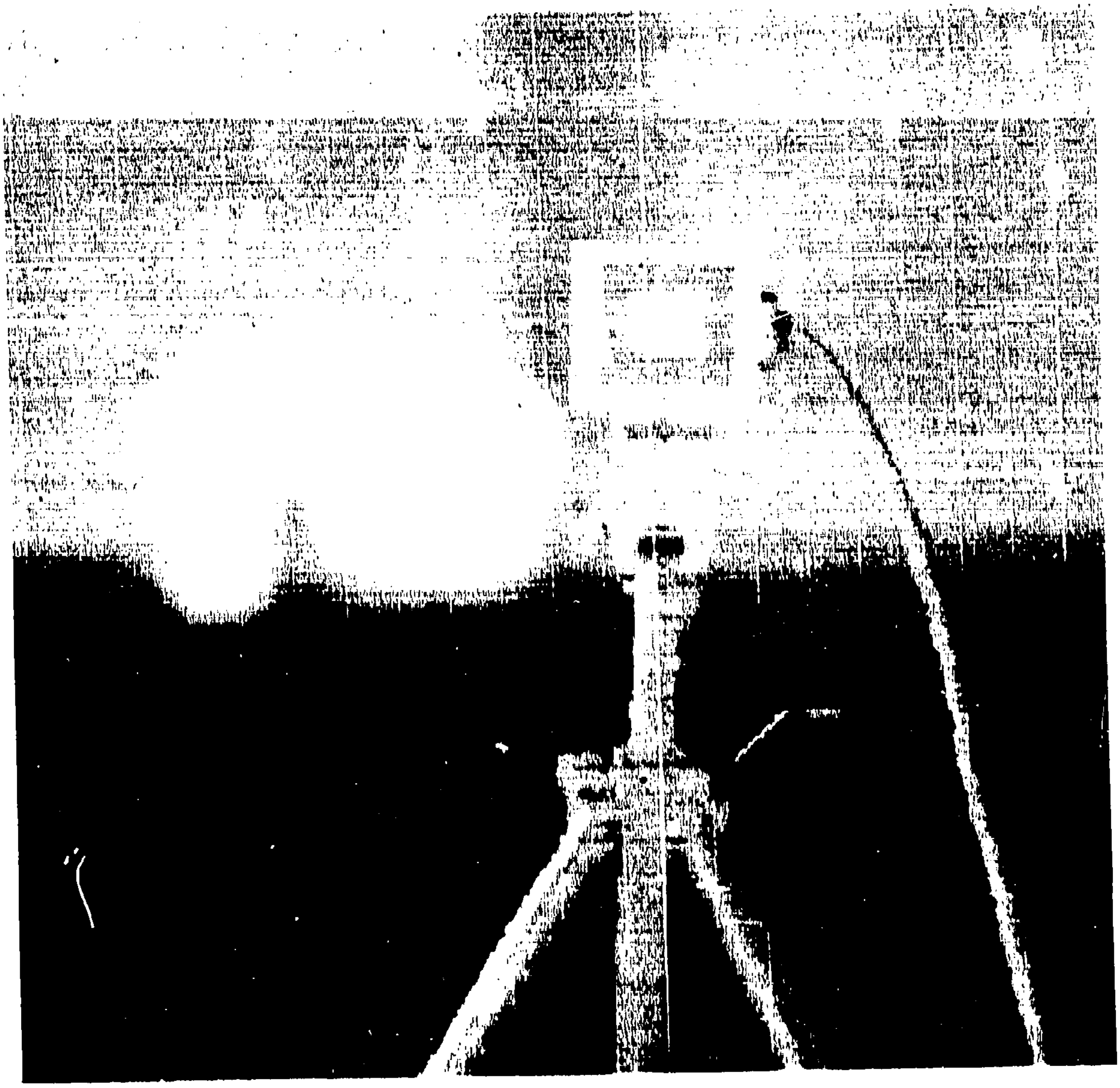


Figure B-5

BLACKBODY AT 25°C

Figure B-6

CARS IN PARKING LOT

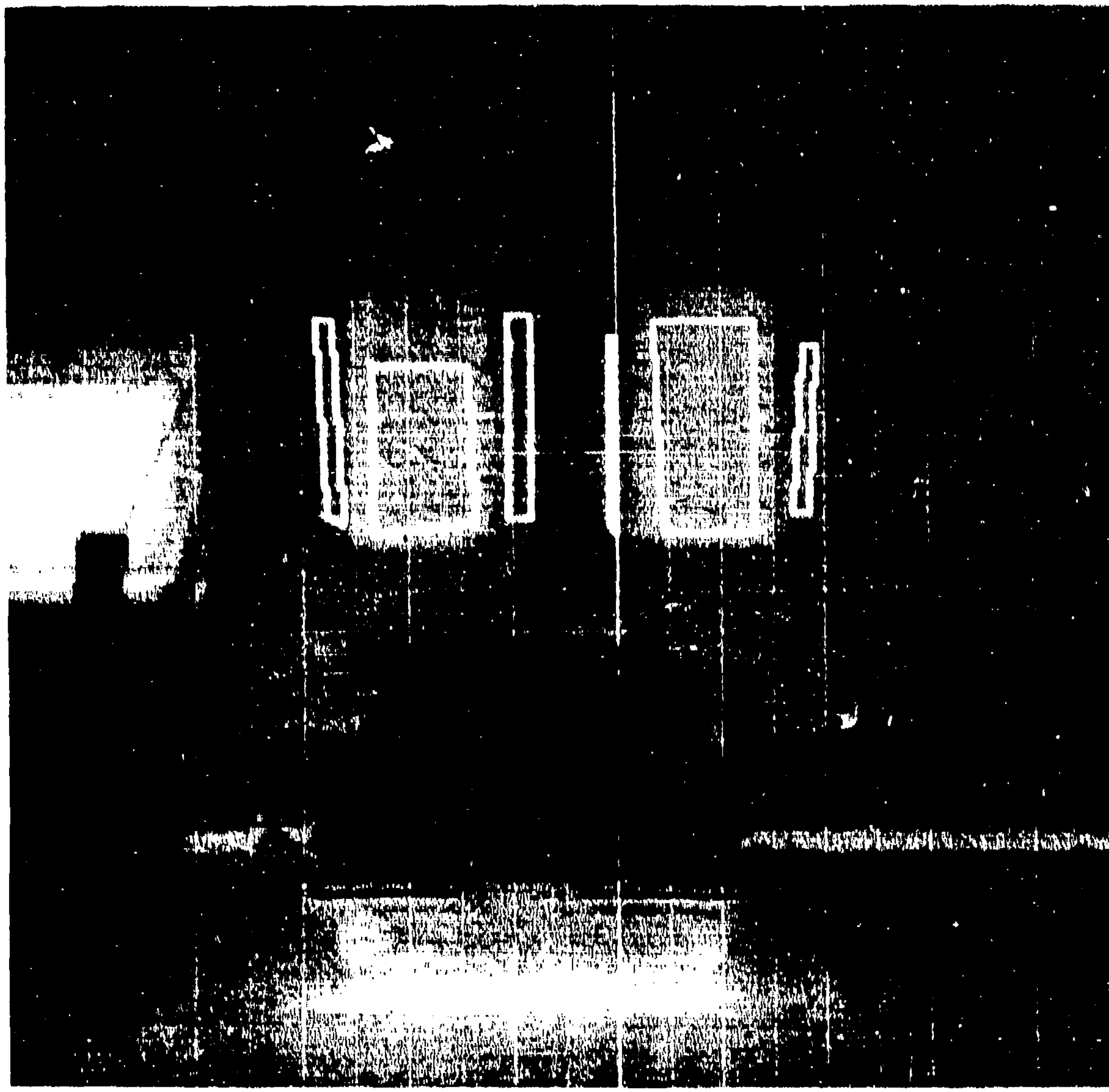


Figure B-7

FEBT WITH DIFFERENTIAL SET POINT AT 1.25°C

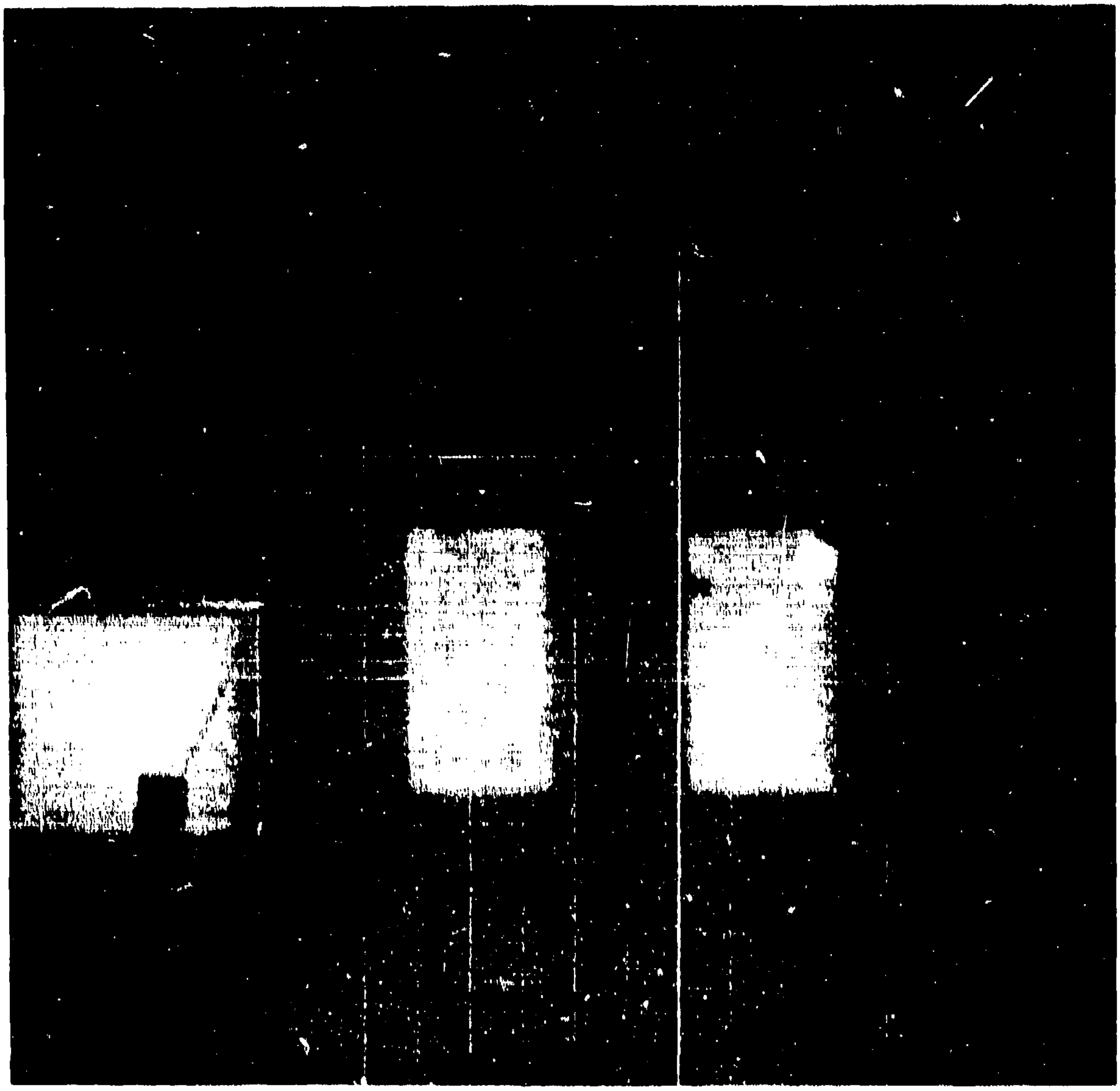


Figure B-8

FEBT-2 WITH DIFFERENTIAL SET POINT AT 3.0° C

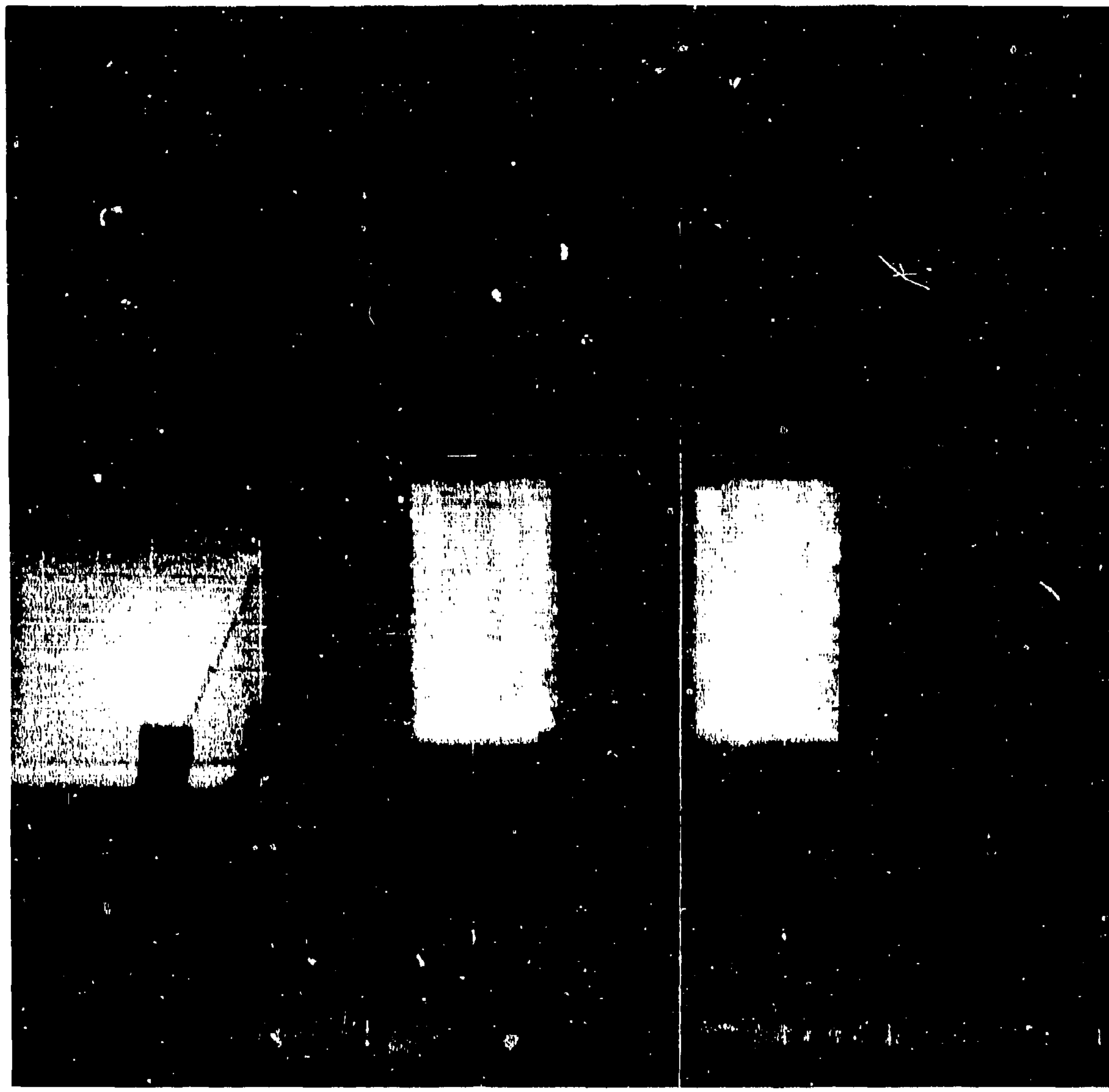


Figure B-9

FEBT-2 WITH DIFFERENTIAL SET POINT AT 5.0°C

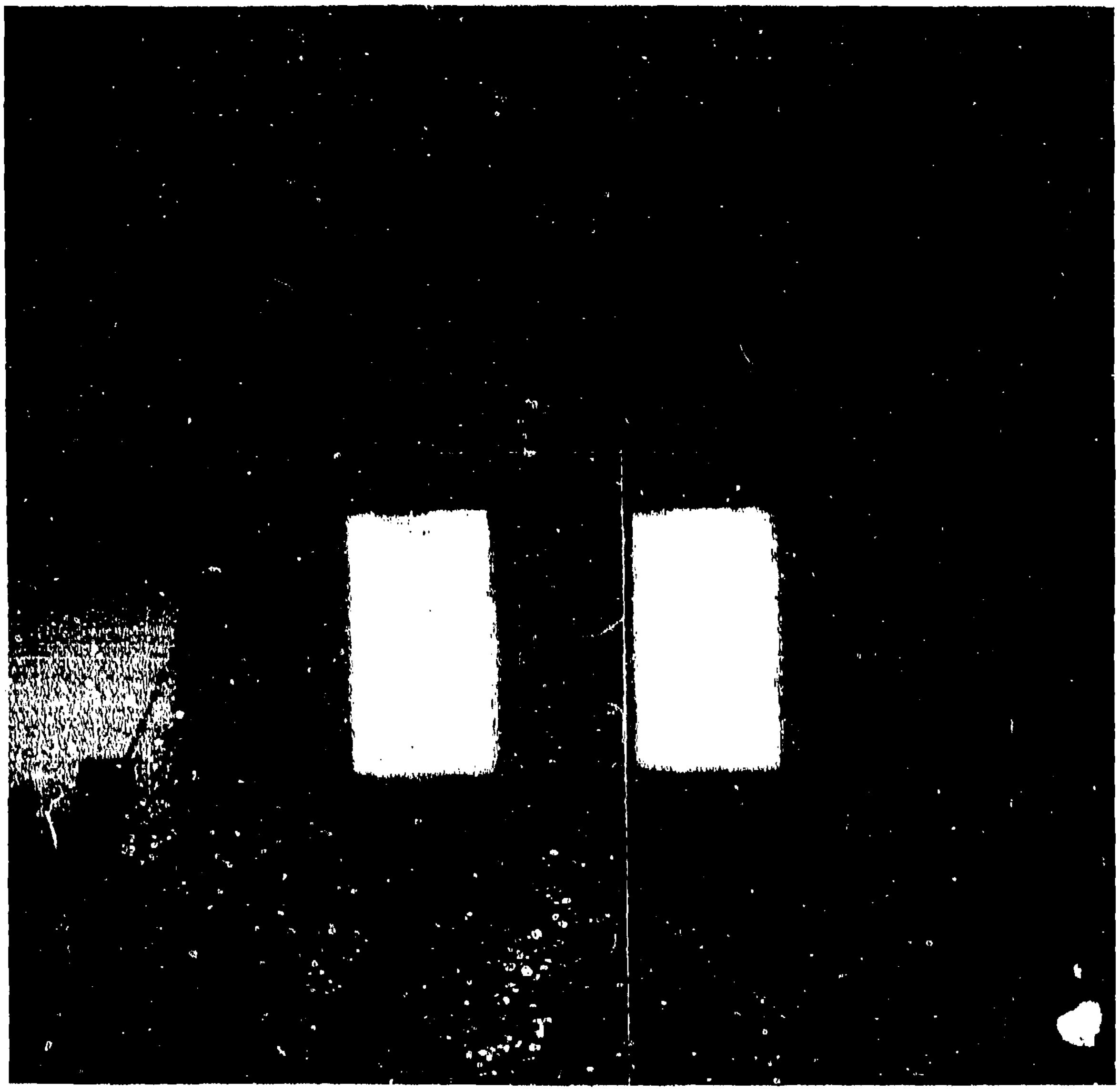


Figure B-10

FEBT-2 WITH DIFFERENTIAL SET POINT AT 7.5°C

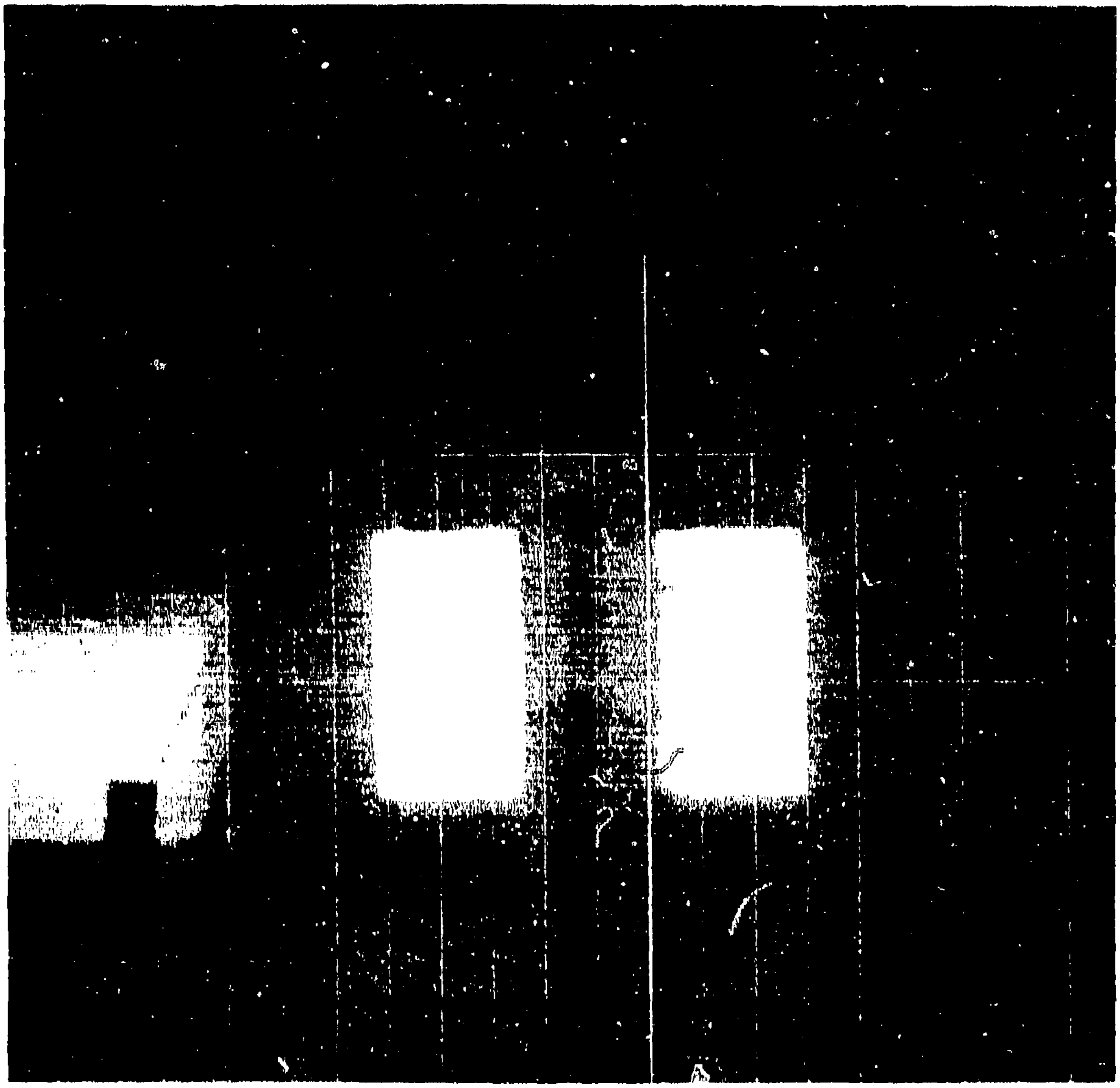


Figure B-11

FEBT-2 WITH DIFFERENTIAL SET POINT AT 10.0°C

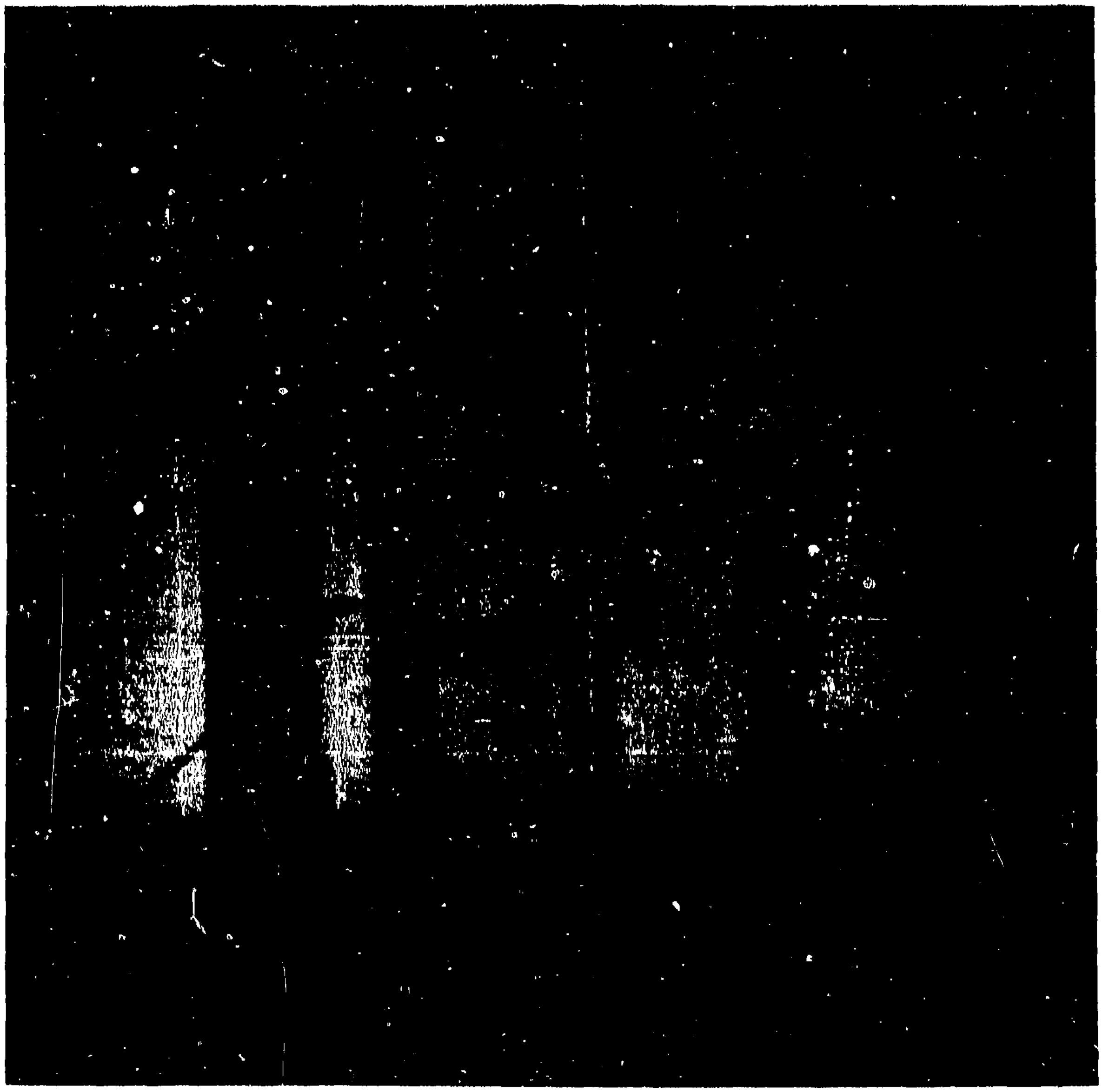


Figure B-12

FEBT-3 WITH DIFFERENTIAL
SET POINT AT 1.25°C

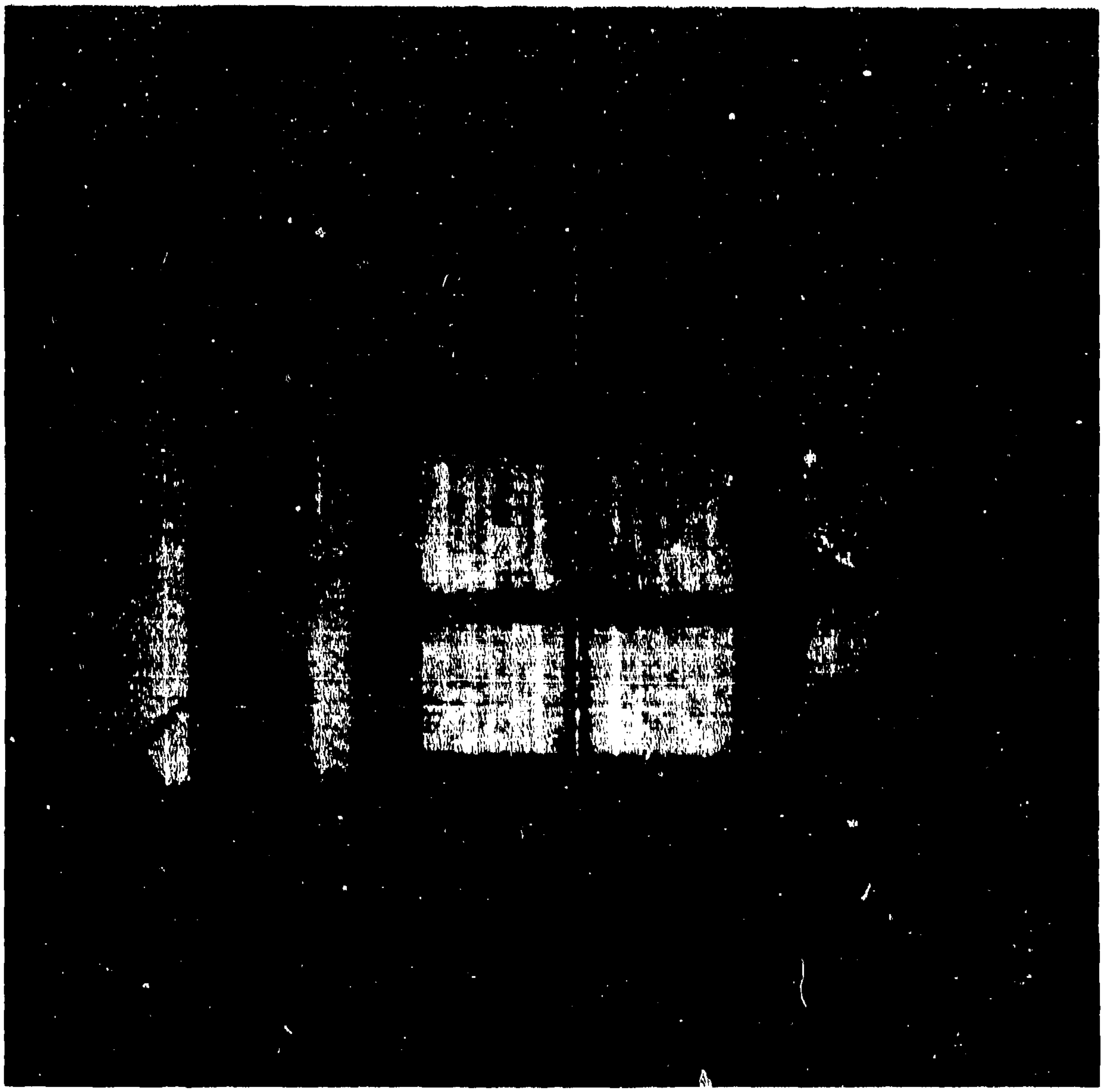


Figure B-13

FEBT-3 WITH DIFFERENTIAL
SET POINT AT 3.0°C

Figure B-14

FEBT-3 WITH DIFFERENTIAL SET POINT AT 5.0°C

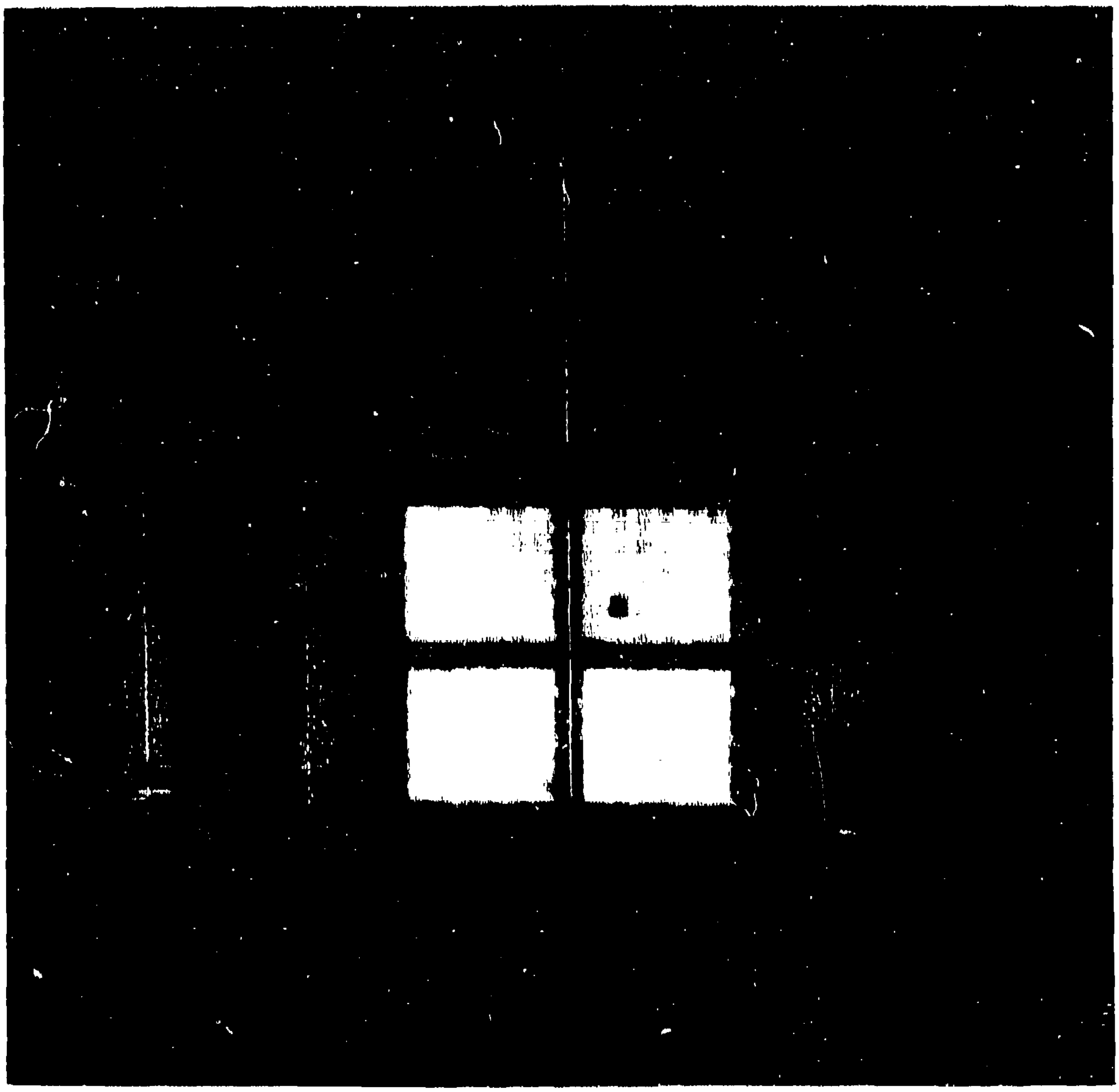


Figure B-15

FEBT-3 WITH DIFFERENTIAL SET POINT AT 7.5°C

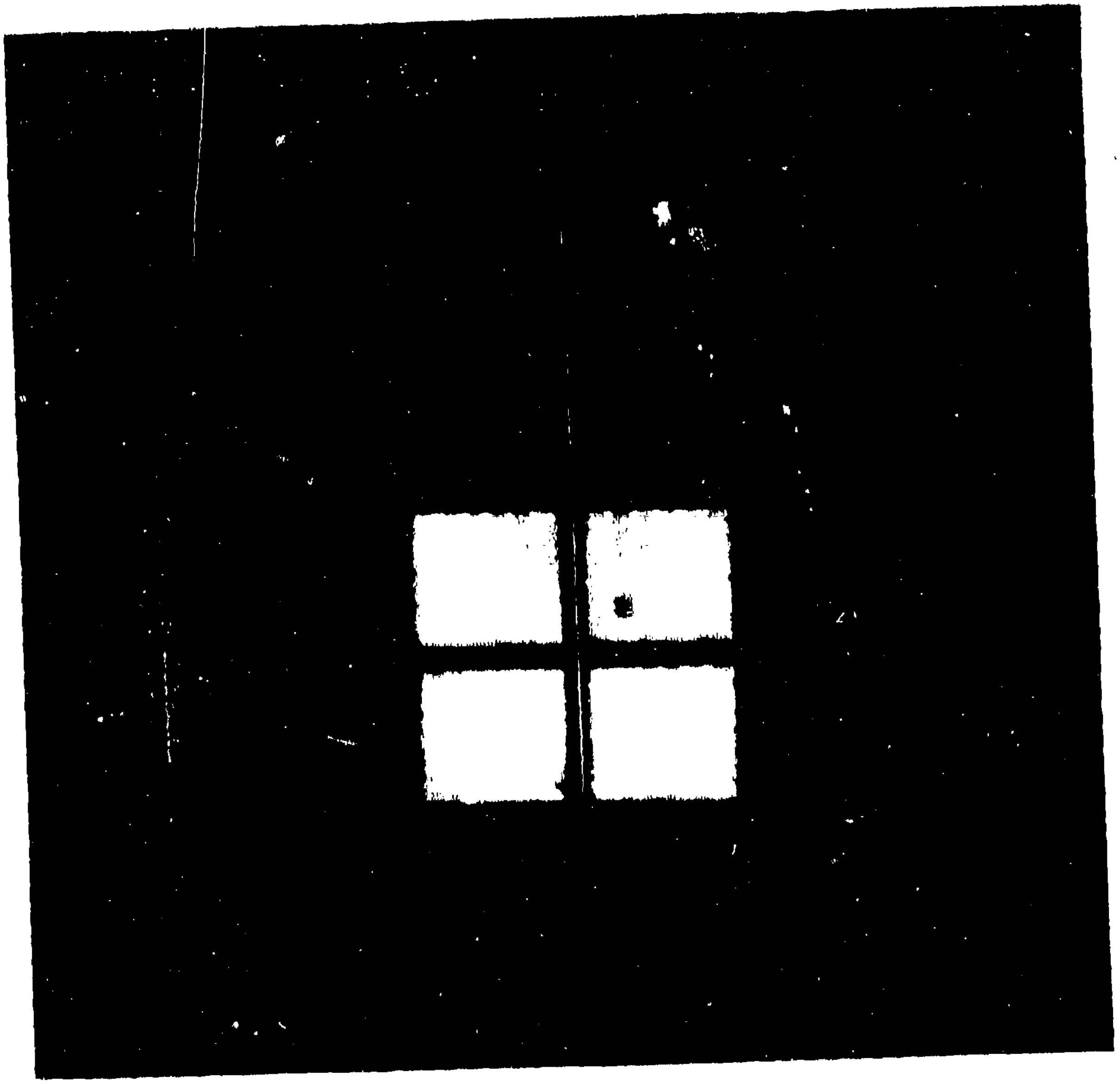


Figure B-16

FEBT-3 WITH DIFFERENTIAL SET POINT AT 10.0°C

APPENDIX C

Funding Data

Financial:

Estimate Man-Hours

	FY 78	FY 79
Civilian	10	1738
Military	0	0
Contractor	350	0
Total	360	1738

Funding Breakout (Thousands of Dollars)

Civilian Pay and Benefits	$ 0.2	$ 21.3
TDY	0.0	2.0
Supplies/Materials	0.0	0.6
Contract Services	9.8	0.0
Instrumentation/Equipment	0.0	108.5
Other		
NV&EOL Feasibility Study	--	5.0
NV&EOL Work Order (Suport Serv.)	--	5.0
Equipment Loans	--	.1
Total	$10.0	$142.5

APPENDIX D

PROPOSAL:

Feasibility Investigation to Establish
An Infrared Target Array Test Range

a. Title: Feasibility Investigation to Establish an Infrared Target Array Test Range

b. Principal Investigator: Mr. Edward Scott, Autovon 899-3111

c. Objective: To examine the feasibility of establishing an Infrared Target Array Test Range for the field test and evaluation of complex airborne and ground-based weapon systems incorporating thermal imaging systems (night vision devices).

d. Relevance: Present field test and evaluation techniques for weapon systems containing thermal imaging systems involve a makeshift range tailored to the specifics of the individual weapon. Development of a range dedicated to the testing of thermal imaging systems in both airborne and ground-based weapon systems would provide a highly cost-effective range. All testing would be in a compact environment, eliminating the need for makeshift evaluation instrumentation, makeshift range development, makeshift targets, and the logistics nightmare of coordinating the developments and acquiring specialized real-scene object targets, such as tanks, trucks, etc.

e. Related Work: U.S. Army Contract DAAD01-79-C-0037, Field Equivalent Bar Targets

f. Technical Approach: Feasibility studies will address the location of a potential range site, address the design/development constraints imposed upon a unique set of thermal targets (optical test patterns and real-scene objects), optimize a range concept design, and prepare a detailed proposal and cost estimate for range development and target/instrumentation acquisition.

g. Schedule and Funding: Feasibility studies to address the above points are estimated to require 6-9 months to adequately derive the range/target requirements.

Personnel Compensation	22.0K
Travel/TDY	3.0K
Materials/Supplies	0.5K
Equipment/Services	4.5K
Total	30.0K

APPENDIX E

Distribution List

DISTRIBUTION LIST

NAME AND ADDRESS	NO. OF COPIES
Commander U.S. Army Materiel Development and Readiness Command ATTN: DRCRD (Tech Library) DRCDE-R (Mr. Butler) 5001 Eisenhower Avenue Alexandria, VA 22333	 1 1
Commander Department of the Army Attn: DAMA-AR DAMA-PPM-T (MAJ Kucharski) Washington, DC 20310	 1 1
Commander U.S. Army Missile Command ATTN: Tech Library Redstone Arsenal, AL 35809	 1
Commander ARRADCOM ATTN: SARPA-TS-T Dover, NJ 07801	 1
Commander U.S. Army Armament Materiel Readiness Command ATTN: Tech Library Rock Island, IL 61201	 1
Commander U.S. Army Engineer Research and Development Laboratories ATTN: Tech Library Fort Belvoir, VA 22060	 1
Director U.S. Army Night Vision and Electro- Optics Laboratory ATTN: Tech Library DELNV-V1 Fort Belvoir, VA 22060	 1 1
Commander U.S. Army Test and Evaluation Command ATTN: DRSTE-AD-I DRSTE-AD-I (Mr. Milway) Aberdeen Proving Ground, MD 21005	 3 1

NAME AND ADDRESS	NO. OF COPIES
Commander	
US Army OTEA	
ATTN: STE-STS-I (Mr. O'Brien)	
Falls Church, VA 22554	1
Commander	
USAAVNDTA	
ATTN: STEBG-DS (Mr. Rogers)	
Ft. Rucker, AL 36362	1
Commander	
U.S. Army Electronics Proving Ground	
ATTN: Tech Library	1
STEEP-MT-I (Mr. Moody)	1
STEEP-MT-DA	1
Fort Huachuca, AZ 85613	
Commander	
U.S. Army White Sands Missile Range	
ATTN: STEWS-NR-D/ID-0	1
STEWS-NR	1
STEWS-TP	1
STEWS-IO	1
STEWS-PL	1
STEWS-TE	1
STEWS-TE (Mr. Werneking)	1
White Sands Missile Range, NM 88002	
Commander	
US Army Aberdeen Proving Ground	
ATTN: STEAP-MT-G	
Aberdeen Proving Ground, MD 21005	1
Commander	
US Army CDEC	
ATTN: ATEC-TC-ELS (LT Shepard)	
Ft. Hunter Liggett, CA 93928	1
Commander	
TCATA	
ATTN: ACS/INST (COL Todd)	1
ATCAT-I-IPD (Mr. Menefee)	1
Ft. Hood, TX 76544	
Commander	
US Army Dugway Proving Ground	
ATTN: STEPD-MT	1
STEPD-PP	1
STEPD-SD	1
Dugway, UT 84022	

NAME AND ADDRESS	NO. OF COPIES
Commander US Army Jefferson Proving Ground ATTN: STEJP-TD-A Madison, IN 47250	1
Commander US Army Cold Regions Test Center ATTN: STECR-TD-EC APO Seattle, WA 98733	1
Commander US Army Tropic Test Center PO Drawer 942 (Mr. Riggs) APO Miami, FL 34004	1
Commander Defense Technical Information Center ATTN: Document Service Center Cameron Station Alexandria, VA 22314	2
Commander Naval Surface Weapons Center ATTN: Tech Library Silver Spring, MD 20910	1
Commander Naval Sea Systems Command ATTN: Tech Library Washington, DC 20362	1
Commander Naval Air Systems Command ATTN: Tech Library AIR 5301 A Washington, DC 20361	1 1
Commander Naval Weapons Center ATTN: Tech Library China Lake, CA 93555	1
Commander Air Proving Ground Center ATTN: Tech Library Eglin Air Force Base, FL 32542	1
NASA Scientific and Technical Information Facility PO Box 33 ATTN: Acquisitions (S-AK/DL) College Park, MD 20740	1

NAME AND ADDRESS	NO. OF COPIES
Library of Congress ATTN: Science and Technology Division Washington, DC 20540	1
National Bureau of Standards ATTN: Tech Library Washington, DC 20234	1
TVI Corporation ATTN: Mr. Steve Rosa, VP 4261 Howard Avenue Kensington, MD 20795	3
Program Manager Advanced Attack Helicopter, DARCOM Attn: DRCPM-AAH P.O. Box 209 St. Louis, MO 63166	1
Dr. Henry Register 3246th Test Wing/TFO Eglin Air Force Base, FL 32542	1
CPT Smith AFWAL/AARI-3 Wright Patterson Air Force Base, OH 45433	1
Commander Naval Research Laboratory Electro-Optical Technology Project Office Washington, DC 20375	1
Commander Naval Air Test Center Attn: Tech Library Patuxent River NAS, MD 20670	1
Commander Air Force Avionics Laboratory Attn: Tech Library Wright-Patterson Air Force Base, OH 45433	1
Commander Air Force Special Weapons Laboratory Attn: Tech Library Kirtland Air Force Base, NM 88830	1
Commander U.S. Army Yuma Proving Ground ATTN: STEYP-MTE	1
STEYP-MTS	1
STEYP-MAA	1
STEYP-MAA (Ramsdell)	1
STEYP-PCC (Sanborn)	1
Yuma, AZ 85364	