AD-A191 471 DEVELOPMENT AND VALIDATION OF TRANSMISSION MEASUREMENTS 1/1
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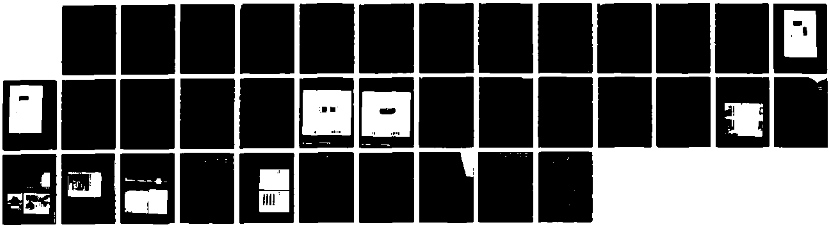

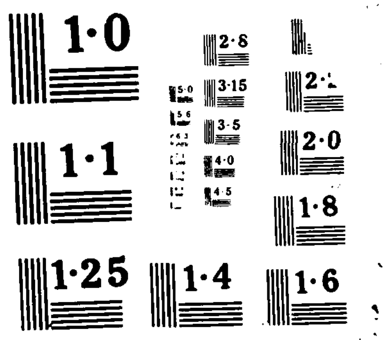
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הטכניון - מכון טכנולוגי לישראל
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Technion - Israel Institute of Technology
Department of Physics

מרכז למחקר באלקטרו-אופטיקה

ELECTRO-OPTICS RESEARCH CENTER

(2)

CONTRACT No. DAJA 45-86-C-0045 JANUARY 1987

1/11/86 - 31/12/86

FIRST INTERIM REPORT

Development and Validation of Transmission Measurements Techniques of Image Contrast, Utilizing Existing IR Imagers.

by

Dr. Ami Ben - Shalom

Dr. Adam D. Devir

United States Army

This research is being conducted at Technion Research and Development Foundation Ltd. Under Contracr No. DAJA 45-86-C-0045 and has been made possible through the support and sponsorship of the U.S. Government through its European Research Office of the U.S. Army. ~~This report is intended only for the internal management use of the Contractor and the U.S. Government~~.

SECOND INTERIM - JUNE 87

THIRD INTERIM - SEPT 87

This interim report summarizes the work done in the first two months of the contract period. The objective was to evaluate different methods proposed for the measurement of atmospheric transmittance with AGA 780 camera. Simultaneously, a computerized formulation was prepored for the data analysis of the output of the AGA system (the data link).

A first field test was performed over a range of 400m. As a result of this experiment a calibration procedure, which is needed for the measurement of an absolute (integrated) atmosphric transmittance, was established. This procedure is needed for further evaluation of the measurement methods.

הטכניון — מכון טכנולוגי לישראל
הפקולטה לפיסיקה
Technion — Israel Institute of Technology
Department of Physics

מרכז למחקר באלקטרו-אופטיקה
ELECTRO-OPTICS RESEARCH CENTER

CONTRACT No. 45-86-C-0045 JUNE 1987
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SECOND INTERIM REPORT

Development and Validation of Transmission
Measurement Techniques of Image Contrast,
Utilizing Existing IR Imagers.

by

Dr. Ami Ben Shalom
Dr. Adam D. Devir
Dr. Leslie B Salem

UNITED STATES ARMY

This research is being conducted at Technion Research and Development Foundation Ltd. Under Contract No. DAJA 45-86-C-0045 and has been made possible through the support and sponsorship of the U.S. Government through its European Research Office of the U.S. Army. ~~This report is intended only for the internal management use of the contractor and the U.S. Government.~~

Introduction

The infrared contrast of a target as recorded by an infrared imager depends upon the intrinsic contrast of the target, the intervening medium between the target and the camera, and the resolution and sensitivity of the recording instrument. The present work was carried out to determine the degradation of the intrinsic contrast of a 3-bar target in the presence of smoke in the optical path between the target and the infrared camera. The infrared imager used in the experiment was a commercially available imaging system, nameley the AGA 780 Thermovision camera with its associated electronic control and recording units.

Theoretical Background

The main aim of the present work was to determine contrast transmittance through a smoke obscurant.The contrast between a target T and a background B can be defined in various ways.The definition used here is

$$C(s)=[L_T(s)-L_B(s)]/L_B(s) \text{---------------} (1)$$

where C is the contrast, s the distance between target and camera, $L_T(s)[L_B(s)]$ the target [background] radiance integrated over the spectrally sensitive band of the instrument. The units of $L_T[L_B]$ are in milli-watt/cm^2/str.

The intrinsic or inherent contrast is given by

$$C(0)=[L_T(0)-L_B(0)]/L_B(0) \quad \text{--------------} (2)$$

where the relevant quantities are defined in the target plane.

The contrast transmittance is then defined as

$$T_c(s)=C(s)/C(0) \quad \text{-------------------------(3)}$$

The use of eqn.(3) requires a knowledge of the intrinsic contrast in the target plane which may not be always available. A way to circumvent this is as follows.

The total radiation incident on the detector is given by

$$L_T(s)=L_T(0)*t(s)+L_p(s) \quad \text{-----------------(4)}$$

where t(s) is the path transmittance , and $L_p(s)$ is the path radiance. A similar expression holds for the total incident radiation from the background on the detector. Using relation (4) in (2) one obtains the following relation for the contrast transmittance:

$$T_c(s)=1/[1+F(s)] \quad \text{---------------------(5)}$$

where $F(s)=L_p(s)/[L_B(0)*t(s)]$.

Thus the contrast transmittance is obtained as a function of the path radiance, the path transmittance, and the background radiance in the target plane.

Experimental set up

The commercially available AGA 780 Dual channel Thermovision system is a very sensitive detector of infrared radiation both in the 3-5 micron and 8-12 micron regions of the electromagnetic spectrum. A schematic diagram of the camera optical head is shown in fig.1. The present work was carried out in the 8-12 micron region only.The relative spectral response of the AGA system is depicted in fig.2 .

The collecting optics consisted of a germanium lens which concentrated the infrared radiation in its IFOV on to a liquid nitrogen cooled detector,with no intervening filter. The infrared image is made up of 64x128 picture elements called pixels. The voltage signals generated at each pixel during the operation of the infrared scanner represent the distribution of infrared energy in the cameras field of view.

The electronic control and data aquisition modules of the AGA system can be used to define a region of interest and obtain maximum,minimum,or average values of the signal in the defined region. The instrument output is in Isothermal Units, which is directly proportional to the collected radiation. In addition to obtaining a direct readout our system is also linked to a IBM-PC micro computer which allows one to record picture frames on a floppy disc. The data on the disc can then be viewed and analyzed at a later time.

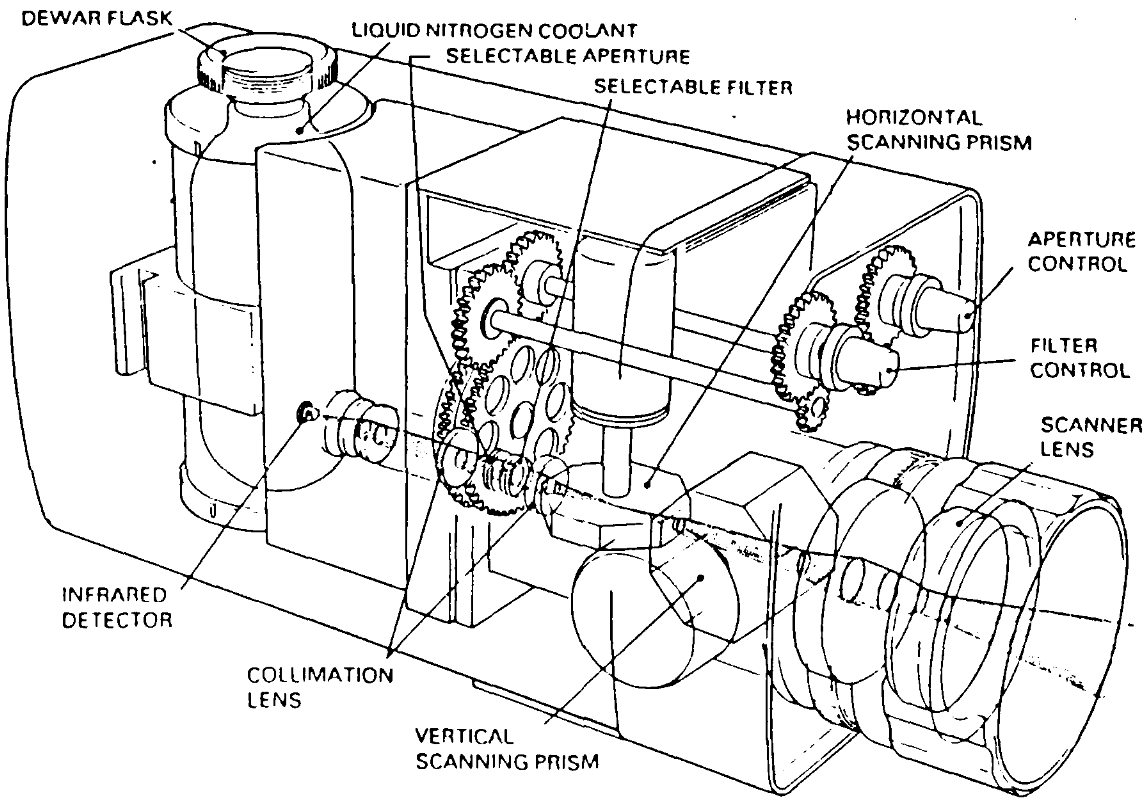


Fig 1: Schematic diagram of the AGA 780 thermovision camera head.

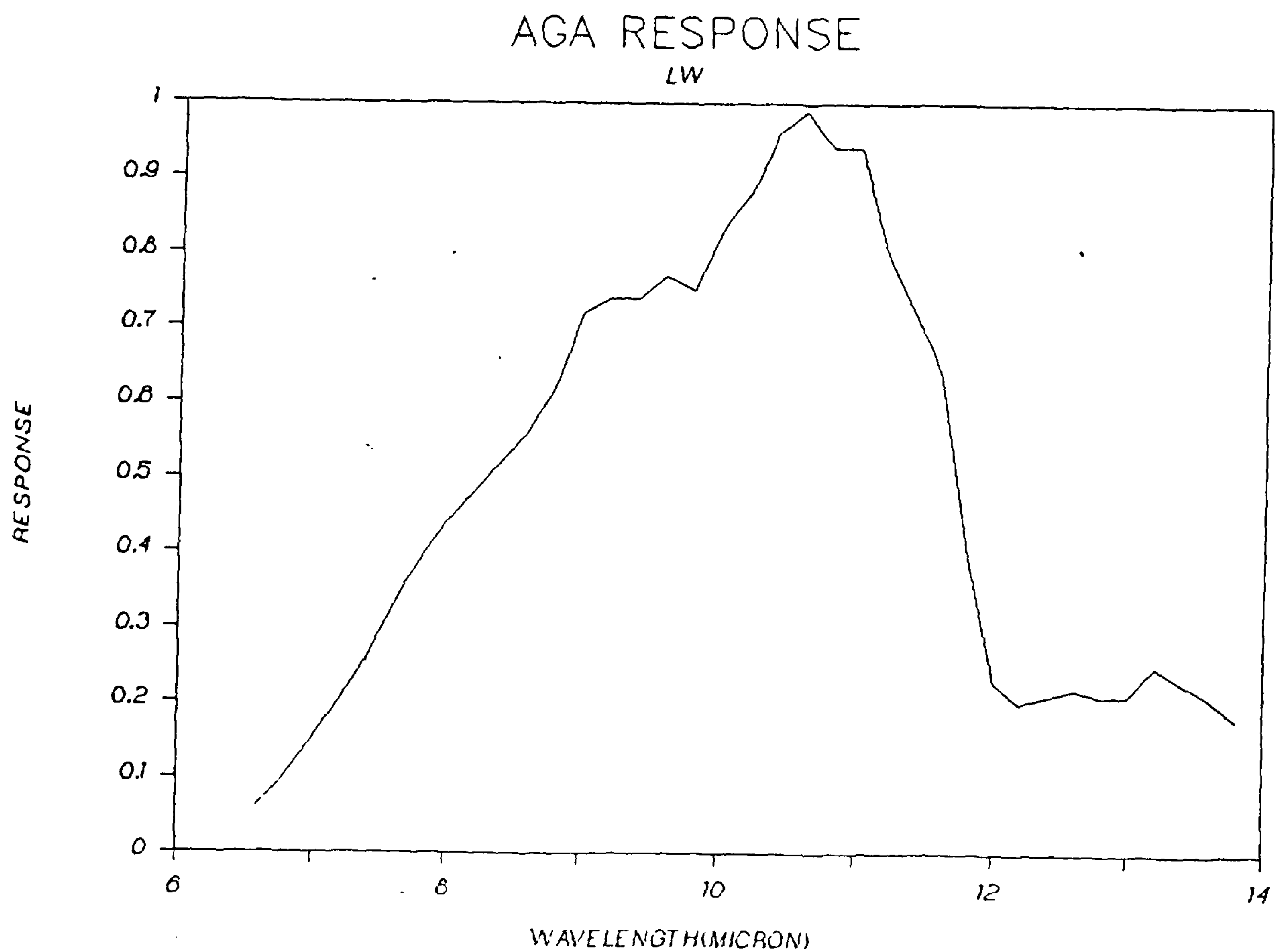


Fig 2: The spectral response curve of the AGA camera in the long wavelength region

The target simulator (for the laboratry experiment only) consisted of three thermoelectric modules, one of which was maintained at a temperature below ambient and the other two at identical temperatures above ambient. Constant temperatures on the surfaces of the thermoelectric devices were achieved by using a stable regulated current source.

The experiments were carried out under laboratory conditions and the distance between the target and the camera was 3.5 meters. The smoke obscurations were carried out near the target plane.

Results

The direct readout of each pixel is given in instrumental units called isothermal units (IU).(IU is the same as volts). The IU value is proportional to the radiation collected by the IFOV of the camera during its scan over the target space. In order to convert the IU values to radiances a calibration of the instrument against a known blackbody source is carried out.(See fig.3). This calibration yields a straight line for a plot of measured IU values versus calculated radiances from the blackbody source at different temperatures. The measured IU values in the experiment can thus be treated to give equivalent radiances at the target plane.

It should be emphasised here that one does not know a-priori the smoke transmittance value and hence we used equation (3) to calculate the contrast transmittance values with a smoke obscurant.

The results obtained are presented as thermal images and a table of values calculated from these images.

A) Fig.4 is a recording of the camera video output. Viewing from left to right the dark square represents the target colder than the surroundings, whereas the two bright squares represent targets warmer than the surroundings. In this case there is no clutter in the optical path between the target and the camera.

Fig.5 is a recording of the same targets in the presence of smoke near the target plane. We plainly see that the contrast between the target and background is greatly reduced, the

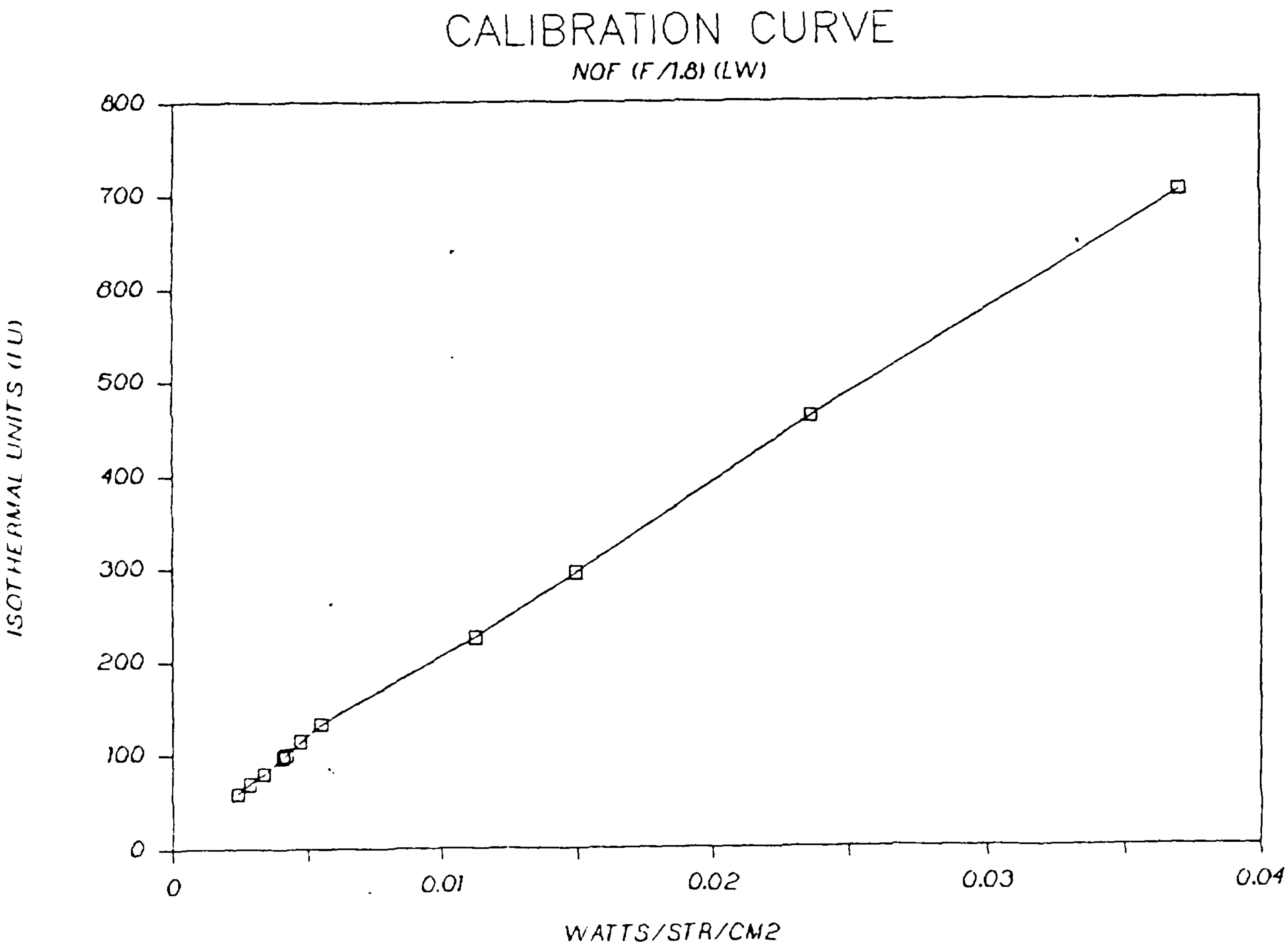
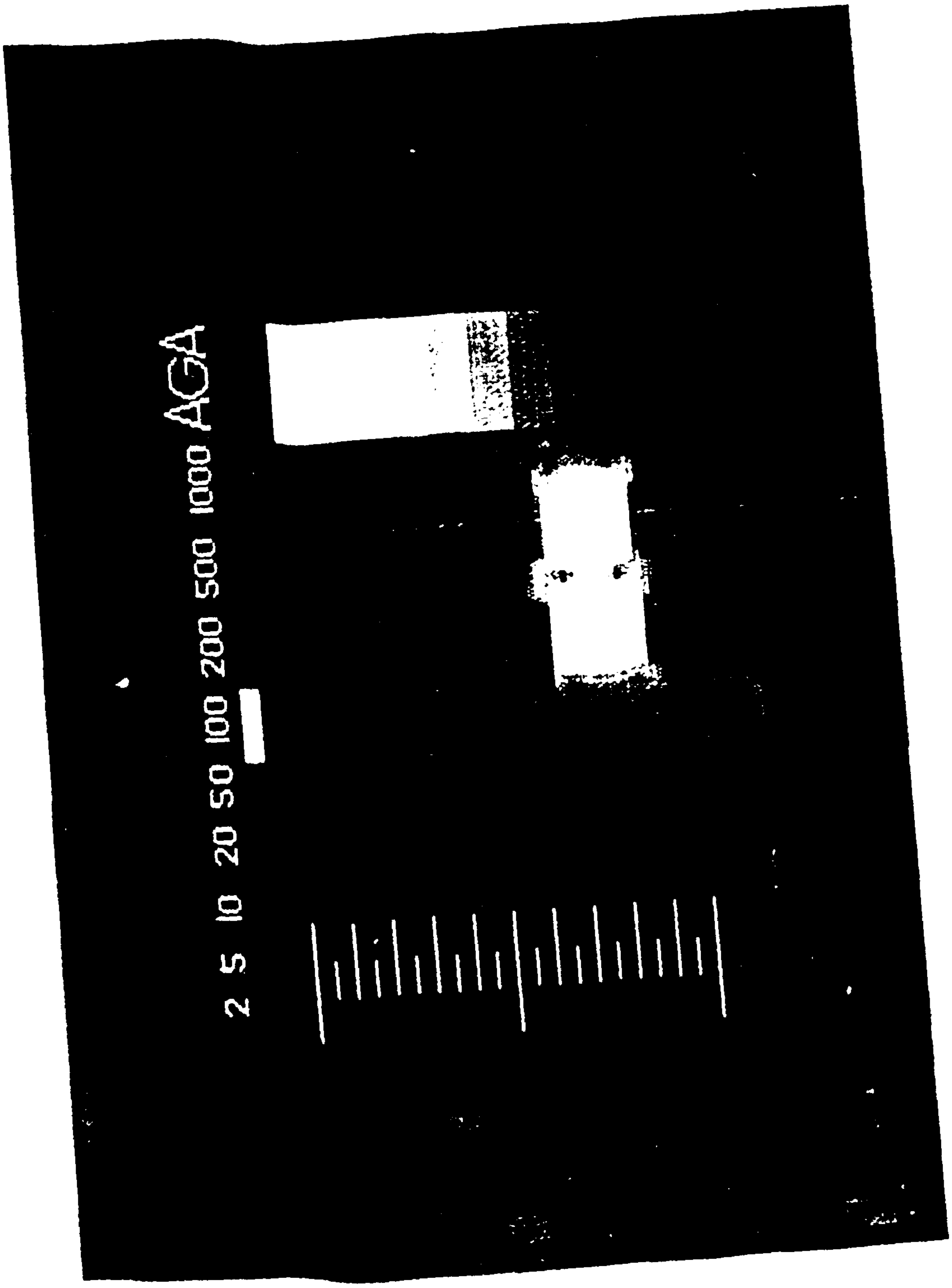


Fig 3: The radiometric calibration curve showing the relationship between the measured signal in IU versus blackbody radiance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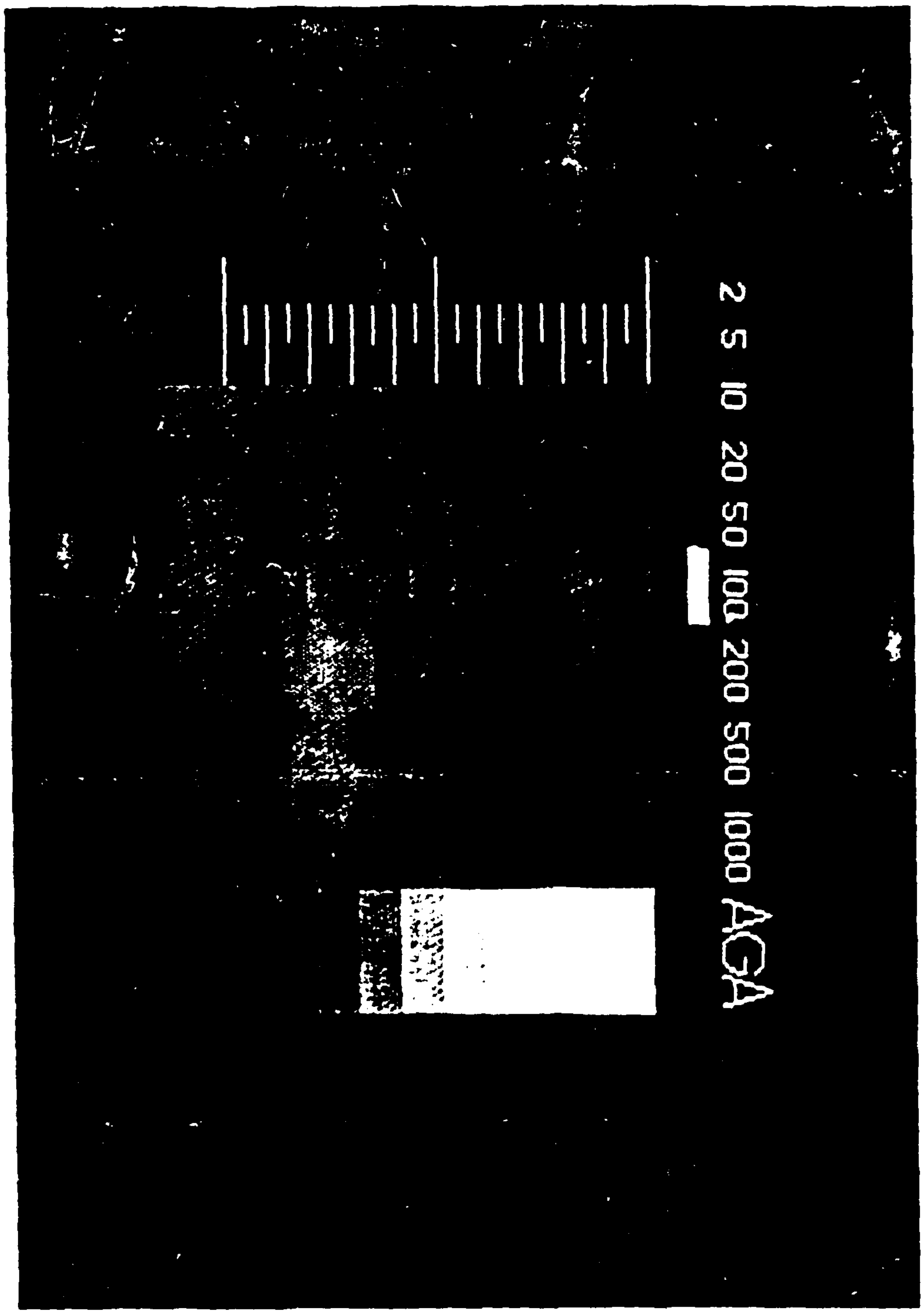
AGA

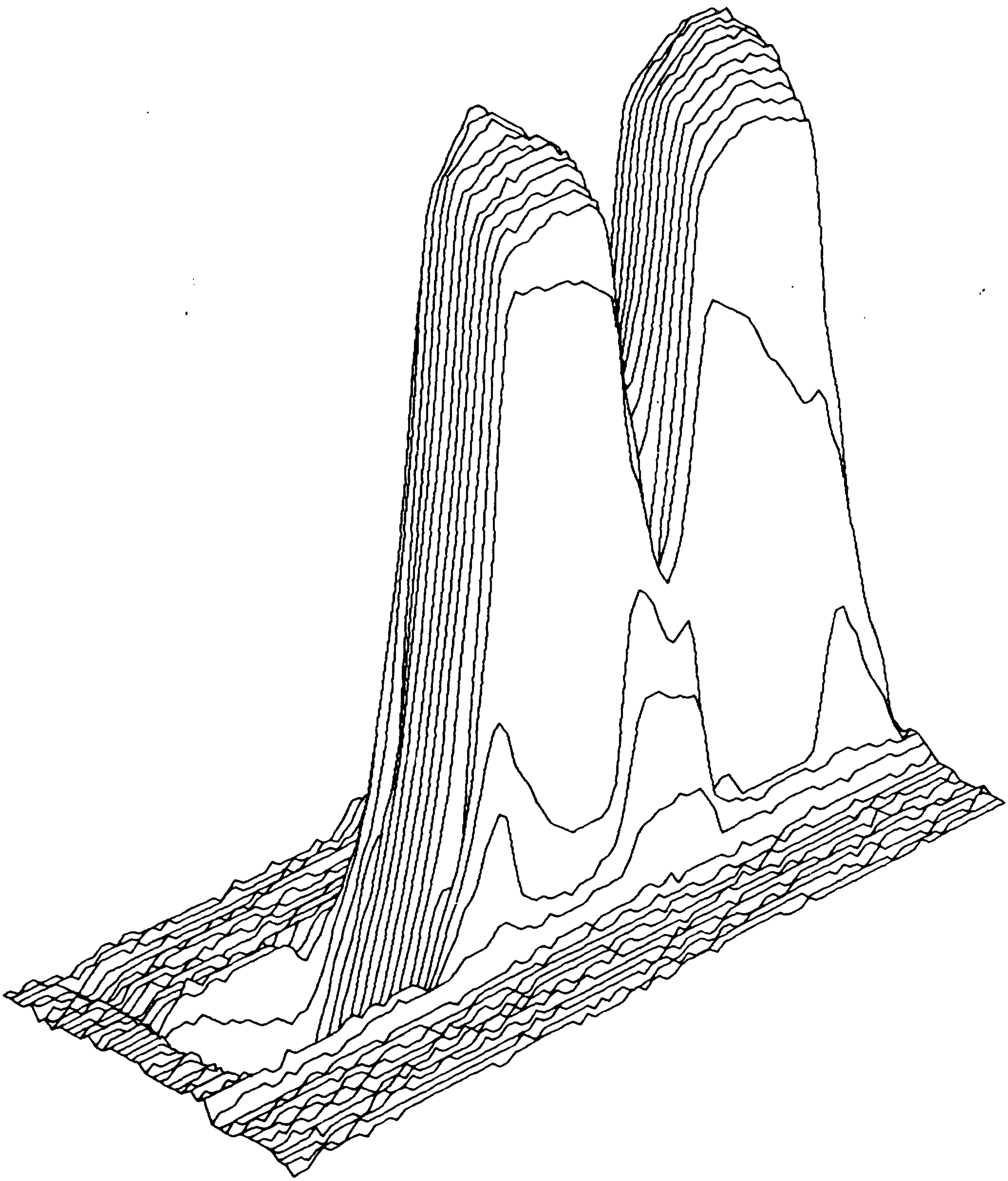

2 5 10 20 50 100 200 500 1000 AGA

signal from the cold target region has been raised whereas that from the warr target region lowered.

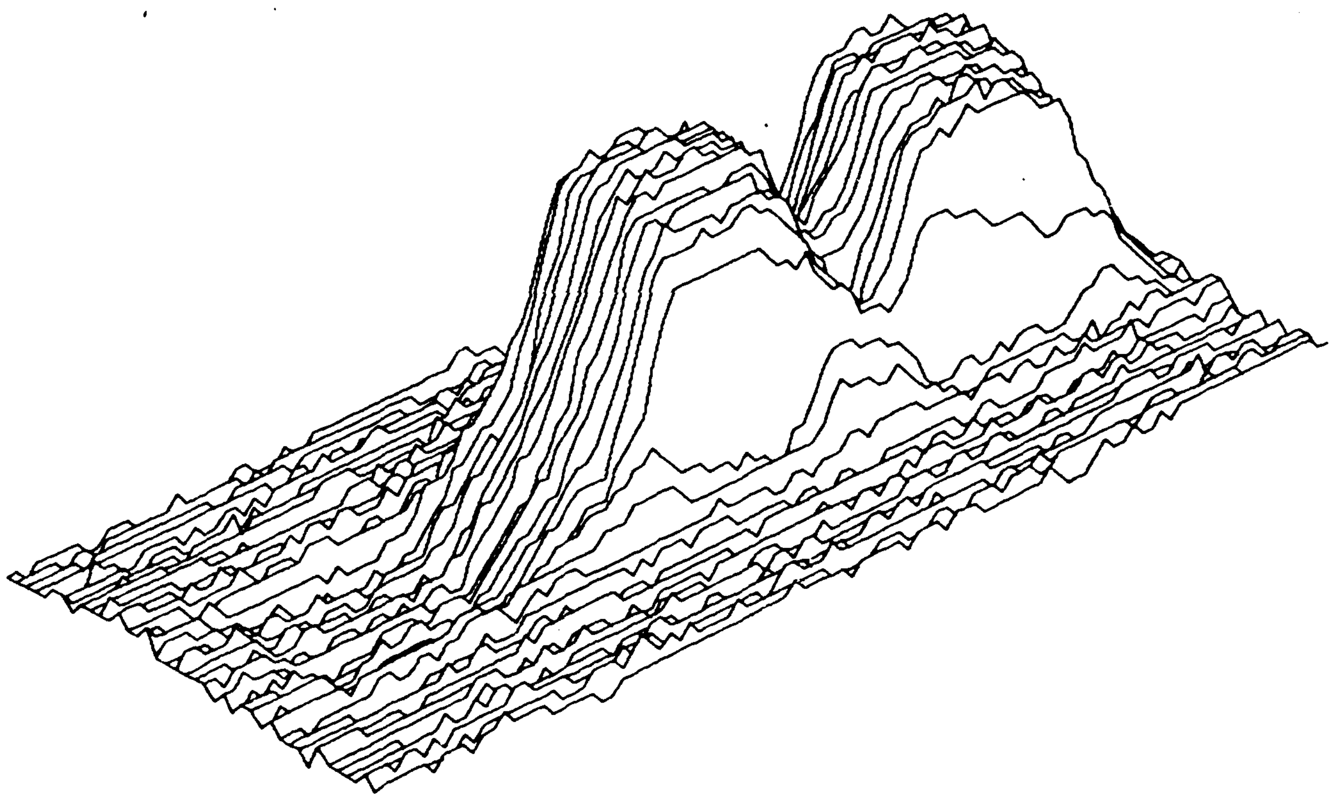
B) Each frame of the recorded picture can be scanned line by line by the computer, either in the vertical or horizontal directions. A horizontal scan through a region of interest containing the targets is represented in fig's.6 & 7. The X and Y directions in these figures represent the geometrical length and breadth of the target whereas the Z axis gives the radiation intensity in units of volts or radiance ($mW/str/cm^2$).

Curve 1 in fig.8 shows a cross section of the target radiances in the target plane with no smoke present. Curve 2 in the same figure represents target radiances in the presence of smoke. Now since the physical temperature and emissivity values of the targets are unaffected by the smoke screen , a ratio of target radiance value with smoke to its value in the absence of smoke gives us the smoke attenuation factor in the 8-12 micron region.

Fig's. 9 & 10 are color plots of the calculated target radiances in the target plane without and with smoke respectively.



TARGET RADIANCE



TARGET RADIANCE WITH SMOKE

Fig 7: Surface relief plot across the same targets in the presence of smoke at the target plane

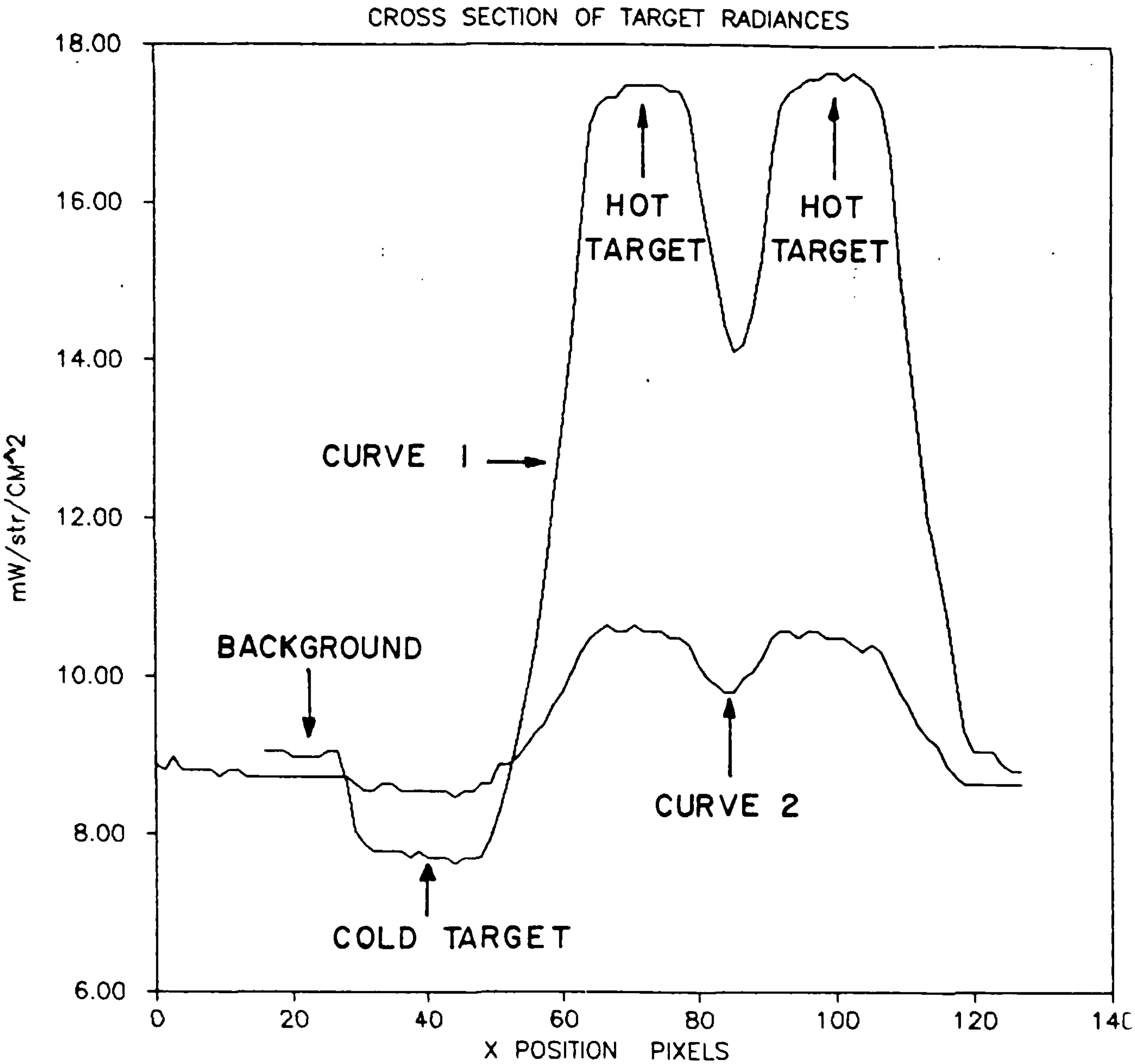


Fig 8: A cross section of target and background radiances along a single horizontal scan. Curve 1 represents values with a clear medium & curve 2 with smoke at the target plane.

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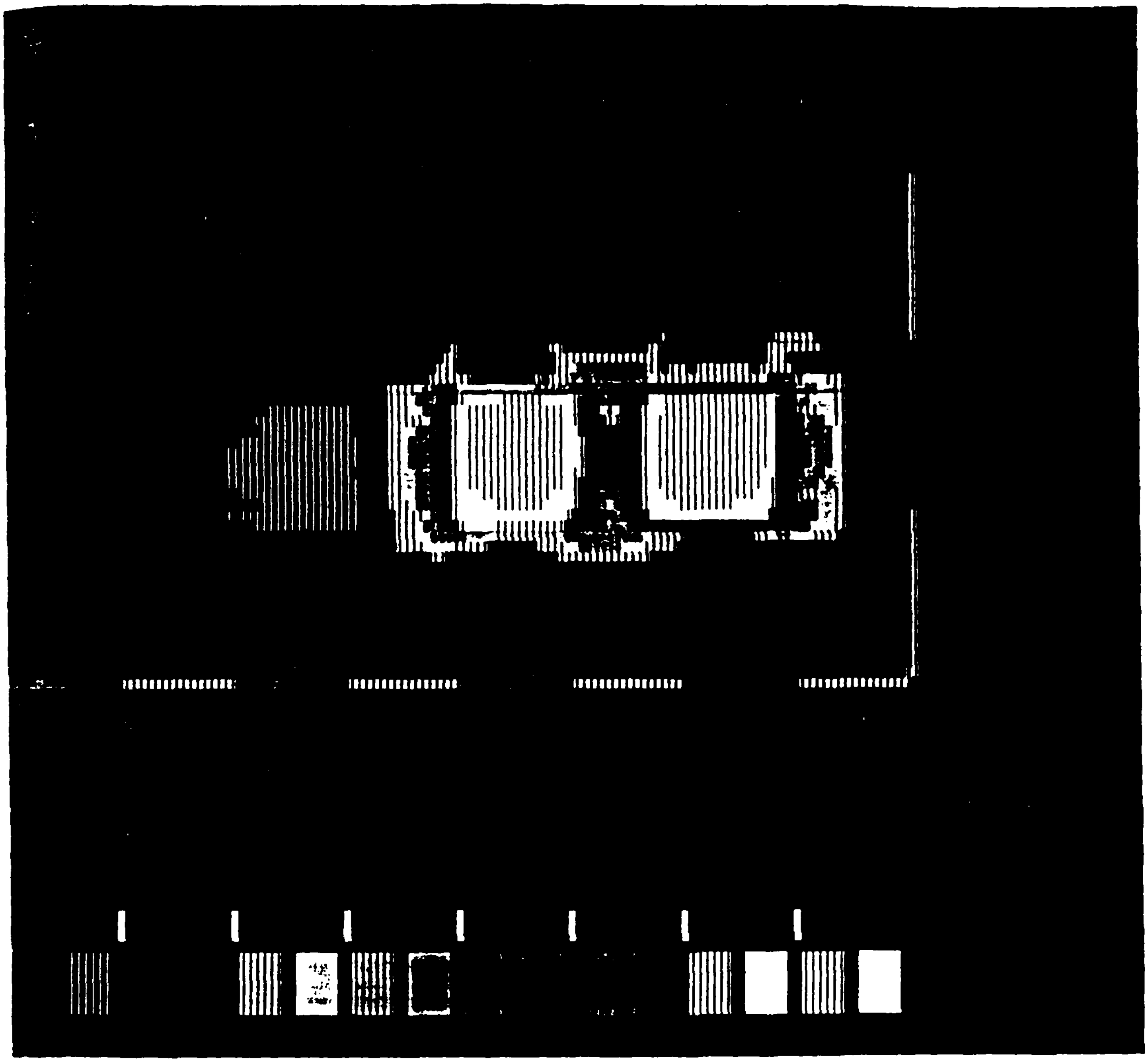


COLOUR to UNITS (W(mili-watt/cm2/str)) table

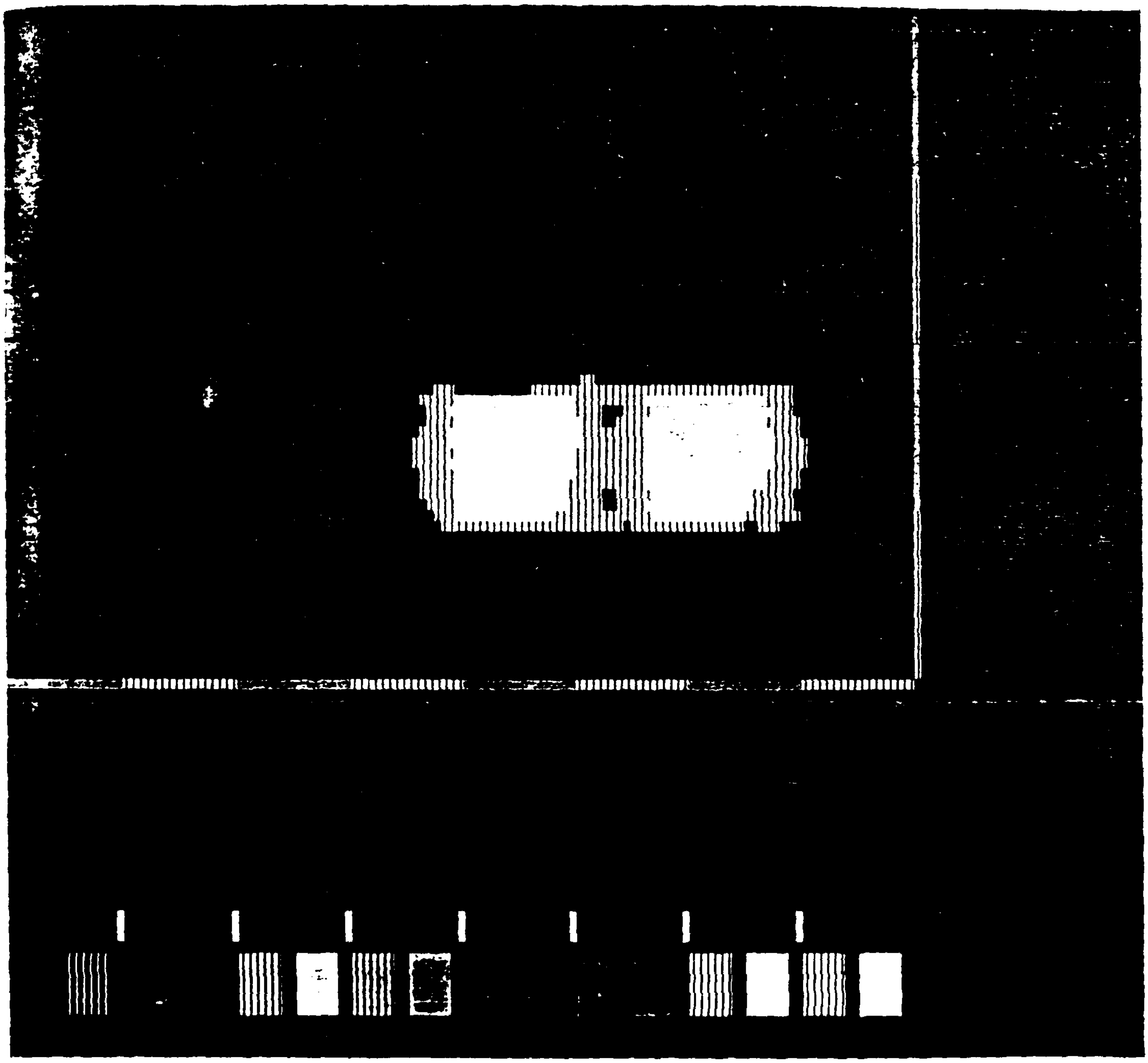
8.55   10.16   11.67   13.28   14.79   16.40   18.00

7.79   9.31   10.91   12.52   14.04   15.64   17.16

Top left point= 0 0 . Magnification X x1.00 Y x1.00

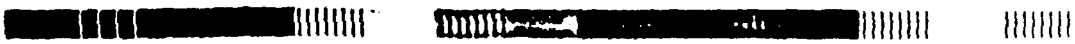
PICTURE: --02aa

smoke simulation:same as no 1 15:29--87/05/24



COLOUR to UNITS (W(mili-watt/cm2/str)) table

8.55 10.16 11.67 13.28 14.79 16.40 18.00



7.79 9.31 10.91 12.52 14.04 15.64 17.16

C) <u>Calculations</u>:

Values for the contrast transmittance of the various targets can be calculated from a line scan of the cross section of the targets and background as shown in fig.8. The signal to noise ratio being large [illegible] this particular recording a single line scan [illegible] enough for analysis purposes. In the case [illegible] there exists the possibility [illegible] scans and thereby obtain an average representative [illegible] the target radiances.

Table 1 contains numerical data derived from the imager. The table is divided into two parts. The upper part gives values of the directly recorded readings in IU of the 3-targets and the surrounding background. Maximum ,Minimum, and Average values of the target surfaces are given in each case.

The lower part of the table represents target and background radiances in the target plane in units of m-watt/cm^2/str. These values were obtained from the calibration and analysis using the AGA-XT computer programme. These values allow us to determine the intrinsic contrast of the targets.

Table 2 contains the results of contrast and contrast transmittance calculations according to equations (1)-(3). The contrast values appearing under the coloumn titled "inherent" are obtained from the target plane radiance values of the relevant quantities. The contrast values appearing under the coloumns titled "clear" and "obscured" are obtained from using directly measured IU values.

The results of table 2 show us that in the presence of smoke the contrast transmittance of the hot objects are reduced by almost 80% of its value in the absence of smoke .The contrast transmittance of the cold object is reduced by 87%.

The smoke attenuation factor for the hot objects is seen to be about 60%. On the other hand there seems to be an enhancement for the cold object. This virtual enhancement may be due to the self emmission of the smoke particles in the optical path.

Another point worth noting from table 2 is that the contrast transmittance calculated with respect to the intrinsic contrast is almost the same as that calculated with respect to the clear contrast value. This would mean that for short path lengths one can obtain contrast transmittance values directly from the IU measurements.

TABLE 1

TARGETS

MEDIUM		Left	Mid	Right	BACKGROUND	UNITS
CLEAR	Max.	46.7	106.7	106.2	53.7	Isothermal Units
	Min.	44.7	99.2	99.2	51.7	
	Avg.	45.7	103.2	104.2	52.6	
OBSCURED	Max.	51.2	63.2	62.7	51.5	
	Min.	50.2	59.7	59.2	50.7	
	Avg.	50.6	62.3	61.7	51.5	
CLEAR	Max.	7.88	18.00	17.92	9.06	$mW/str/cm^2$
	Min.	7.54	16.74	16.74	8.72	
	Avg.	7.71	17.41	17.58	8.88	
OBSCURED	Max.	8.64	10.66	10.58	8.81	
	Min.	8.47	10.07	9.99	8.55	
	Avg.	8.53	10.51	10.41	8.68	

TABLE 2

CONTRAST

TARGET	INHERENT	CLEAR	OBSCURED	TRANSMITTANCE
Left (cold)	-0.132	-0.131	-0.018	0.133
Mid (hot)	0.961	0.962	0.211	0.219
Right (hot)	0.980	0.981	0.199	0.203

Fig 11: Table 1 represents measured (IU) and calculated ($mW/str/cm^2$) values of the tragets & background.
Table 2 gives contrast values for the inherent, clear & obscured cases. The last coloumn represents contrast transmittance values through smoke.

Conclusions.

In concluding this report we can state that the contrast transmittance of targets through smoke, dust, or any other degrading atmospheric condition, can be determined, using existing commercial thermal imagers, an IBM-XT micro computer, and any image processing software. We are now going over to the next stage of the programme where measurements under actual field conditions will be carried out. The hot and cold targets for this "WAR GAME" scenario will be of much larger dimensions, typically 2 x 3 meters in size, and these targets will either be constructed in our laboratory or acquired commercially. See appendix for attached catalogues of these items.

APPENDIX

TCT

THERMAL CROSS PATTERN TARGET

U.S. AESTRA CORP., NEW YORK
AESTRA G.M.B.H., DÜSSELDORF

THERMAL CROSS PATTERN TARGET
PRELIMINARY DRAFT

GENERAL DESCRIPTION

For simulation of various thermal targets in battle field environment, in opposition to thermal viewer and systems

TECHNICAL DATA

Dimensions 240 x 240 cm

Thermal signature dimensions 240 x 240 cm or (240 x 320 cm)

Spatial thermal signature 768 single elemets (24 x 32 heated spaces)

Weight According to the number of single heated spaces required 4 to 7 kg

Operating Environment For field use portable weather resistant

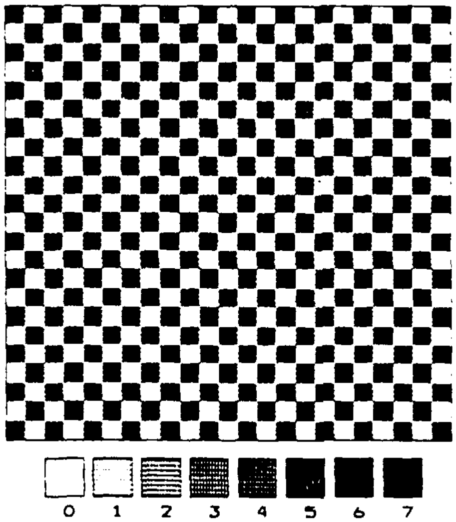
TECHNICAL DESCRIPTION

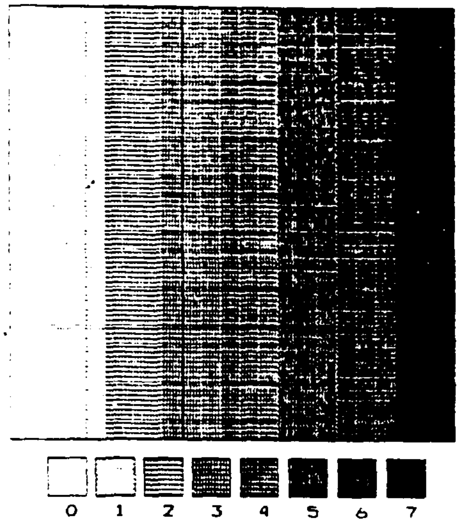
- ★ The thermal cross pattern target is made of 768 single heated elements that can form any pattern or thermal spatial signature with 8 respective temperature levels
- ★ The thermal cross pattern target can be operated with a microprocessor with controls 32 fixed programmed patterns or with a personal computer which can form unlimited number of patterns
- ★ The thermal cross pattern target comes with a wide range of software and instructions to guarantee the comprehensive use of the system
- ★ The size and sequence of the single heated elements of the thermal cross pattern target can be vary according to any requirements and demands.
- ★ The thermal cross pattern target resist, to great extend, temperature fluctuation over the cross pattern target area, caused by influences of wind rain, with the aid of two sided insolation layers
- ★ The thermal cross pattern target can be operated using different types of power sources, such as batteries or transformer
- ★ The thermal cross pattern target can be made to operate according to any other power specifications and requirements
- ★ The thermal cross pattern target is easy to transport It folds into the size of 15 x 30 x 120 cm
- ★ The thermal cross pattern target is easy to install It is tied to a light frame
- ★ The thermal cross pattern target is light Since it is made mostly of foil

U.S. AESTRA CORP.
SUITE 2[illegible]
58[illegible] FIFTH AVENUE
NEW YORK [illegible] U.S.A.
PHONE [illegible]
TELEX 2[illegible]
FAX 212[illegible]

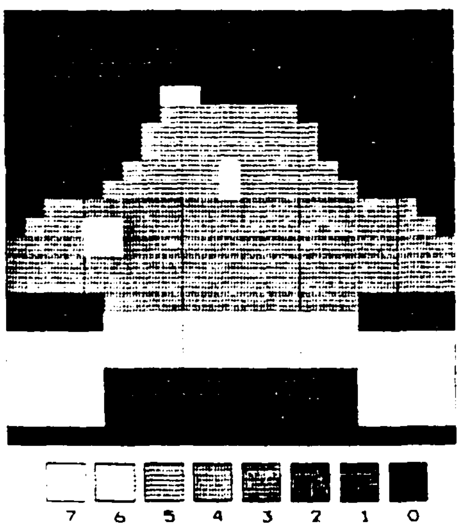
MULTISPECTRAL CAMOUFLAGE
MARKETING DIVISION

EXAMPLE OF THERMAL CROSS PATTERNS





TANK CROSS PATTERN AND ACTUAL PHOTO



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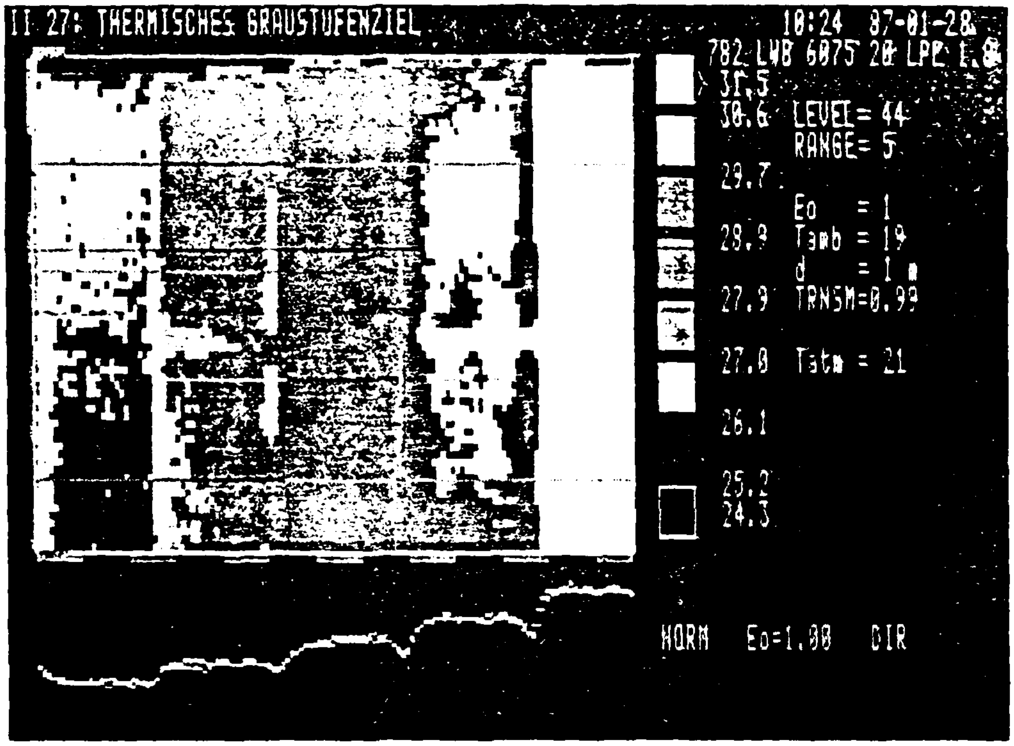
TELEX 8586423 DART D

EXAMPLES OF DIFFERENTIAL CROSS PATTERN IMAGE TARGET



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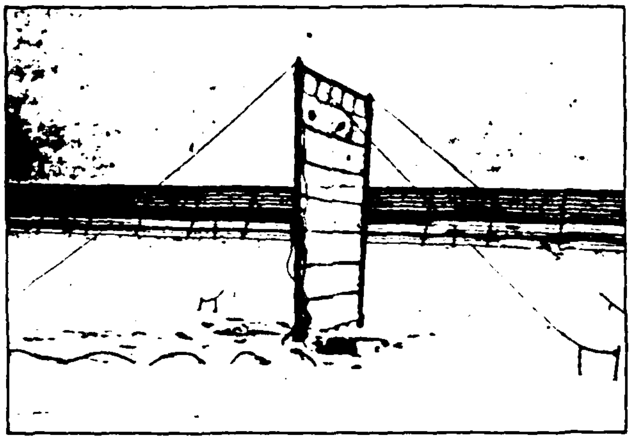
- Before ordering and using, user shall determine the suitability of the product, method of application and the required properties of the products for his intended use, and user assumes all risk and liability whatsoever in connection therewith.

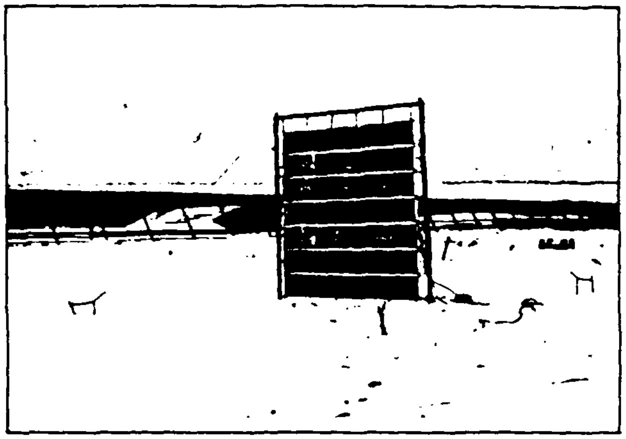
In lieu of all warranties, expressed or implied:

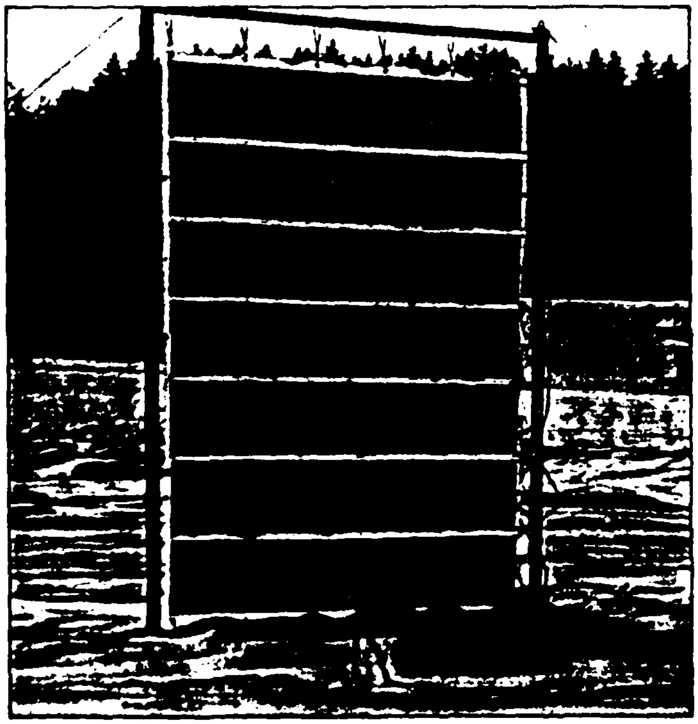
- Seller's and manufacturer's only obligation shall be to replace such quantity of the product proved to be defective.
- Neither seller nor manufacturer shall be liable for any injury, loss or damage, direct or consequential, arising out of the use of or the inability to use the product.

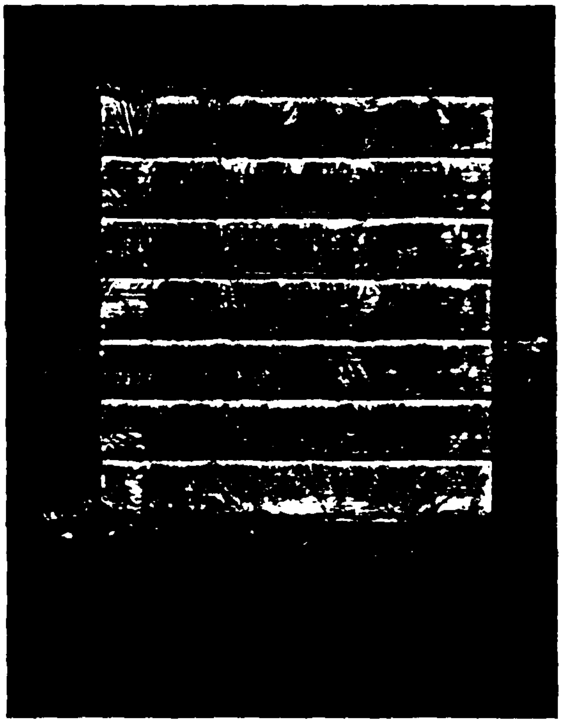
TGT

TERMAL GUIDANCE TARGET









U.S. AESTRA CORP., NEW YORK
AESTRA G.M.B.H., DÜSSELDORF

THERMAL GUIDANCE TARGET
PRELIMINARY DRAFT

GENERAL DESCRIPTION
For training operators for infra red systems in battle field environment.

TECHNICAL DATA
Dimensions: 240 x 240 cm.
Thermal signature dimensions: 230 x 230 cm.
Spatial thermal signature: 3.5 pairs of lines.
Weight: approximatively 4 kg.
Operating environment: for field use, portable and weather resistant.

TECHNICAL DESCRIPTION:
★ The thermal guidance target satisfies the Johnson Criterion for the identification of an armor tank with the use of vertical line structure with four electrically heated lines and three passive lines.

★ The thermal guidance target has a special temperature regulator that can regulate temperature contrasts from 0 kelvin to 30 kelvin. Top temperature recommended is 90 degrees celsius. Irreversible damage to the weather resistance material and structure will occur at temperatures higher than 90 degrees celsuis.

★ The thermal guidance target resist, to great extend, temperature fluctuations over the beam target area, caused by influences of wind and rain, with the aid of two sided insolation layers.

★ The thermal guidance target can be operated using different types of power sources, such as batteries or transformer.

★ The thermal guidance target comes with a primary regulated step down transformer 0 to 230 volt and a secondary transformer 0 to 42 volt and conforms to the VDI safety regulations.

★ The thermal guidance target can be made to operate according to any other power specifications and requirements.

★ The thermal guidance target is very easy to transport. It dolds into the size of 15 x 30 x 120 cm.

★ The thermal guidance target is very easy to install. It is tied to a flight frame.

★ The thermal guidance target is light. Since it is made mostly of foil.

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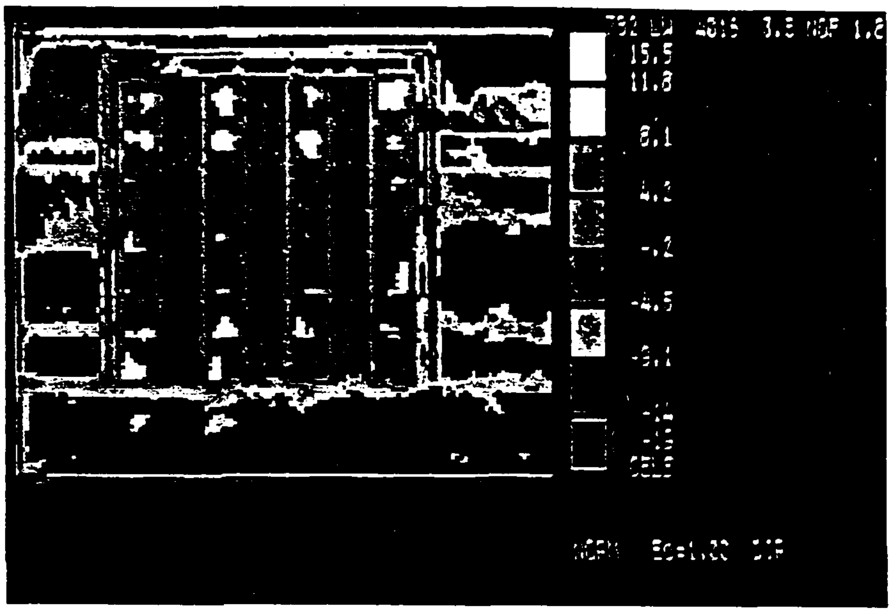
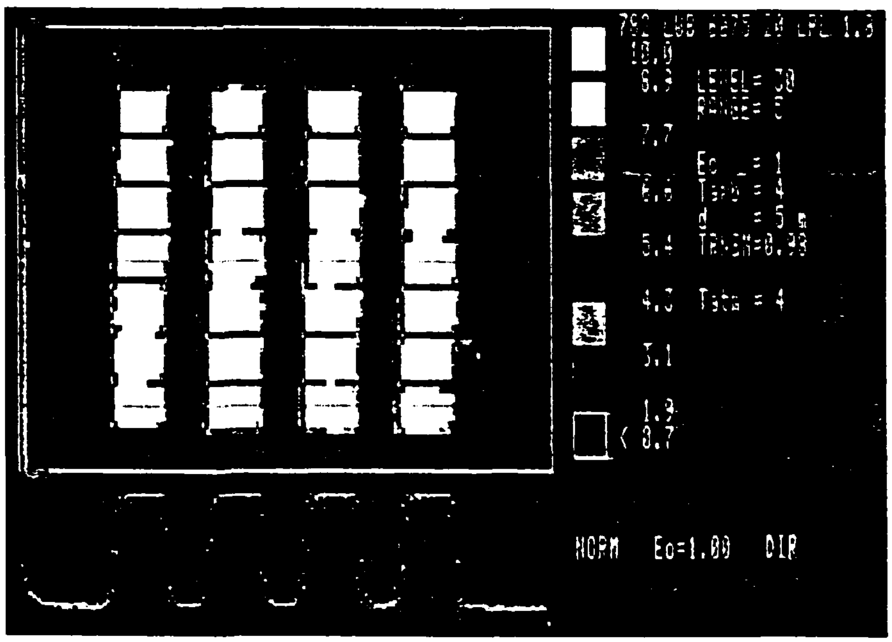
MULTISPECTRAL CAMOUFLAGE
MARKETING DIVISION

EXAMPLES OF THERMAL IMAGES:





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הפקולטה לפיסיקה
Technion — Israel Institute of Technology
Department of Physics

מרכז למחקר באלקטרו-אופטיקה
ELECTRO-OPTICS RESEARCH CENTER

CONTRACT NO. DAJA45-86-C-0045 SEPTEMBER 1987

THIRD INTERIM REPORT

Development and Validation of Transmission Measurements Techniques of Image Contrast, Utilizing Existing IR Imagers

by

Dr. Ami Ben-Shalom

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United States Army

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This interim report summarizes the work done in the third stage of the contract period. The objective was to perform a field test of HOT and COLD IR Targets with existing AGEMA 780 thermal Imager.

Two COLD targets of dimensions 3.5m X 3.5m were built using reflective thermal blankets. By placing the reflective targets at an angle of 45^{o}, to the zenith, one can obtain very strong negative contrast (typically 30^{o}c below background). The optical properties of the reflective thermal blenkets in the 8-12 micron region are included in this report.

The HOT target used is a commercial product from AESTRA having dimensions of 2.3 X 2.3m. They can be maintained at a temperture of 60^{o} above ambient. The details of the hot target as described by the company catalog are also included in this report.

In the month of October 1987, we plan to carry out contrast experiments using the above mentioned hot and cold targets. The target-camera distance will be of the order of hundreds of meter and the thermal images will be recorded with and without white smoke screen. In order to get meaningful results, the target should occupy at least three pixels and cousequently with an IFOV of 0.5mard, the maximum distance to the target will be limited to about 2Km.

ELECTRO - OPTICS RESEARCH CENTER
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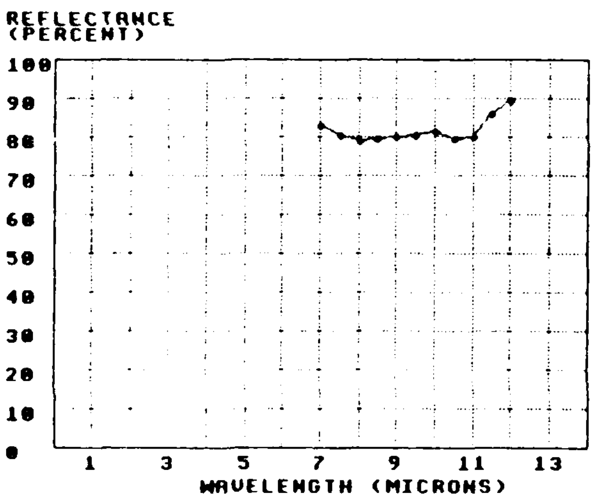
Reflectance Measurements

Date: 08-06-87
Customer: TAMBUR
TECHNION sample no.: 1565/1
Customer sample no.: TERMAL BLANKET

RESULTS FOR SAMPLE: TERMAL BLANKET

Wavelength (Microns)	Reflectance (Percent)
7	83
7.5	81
8	79
8.5	80
9	80
9.5	81
10	82
10.5	80
11	80
11.5	86
12	90



THE RESULTS ARE ACCURATE TO WITHIN +-2% ABSOLUTE REFLECTANCE

U.S. AESTRA CORP NEW YORK
AESTRA G.M.B.H., DÜSSELDORF

THERMAL GUIDANCE TARGET

PRELIMINARY DRAFT

GENERAL DESCRIPTION

For training operators for infra red systems in battle field environment.

TECHNICAL DATA

Dimensions: 240 x 240 cm.
Thermal signature dimensions: 230 x 230 cm.
Spatial thermal signature: 3.5 pairs of lines.
Weight: approximatively 4 kg.
Operating environment: for field use, portable and weather resistant.

TECHNICAL DESCRIPTION:

* The thermal guidance target satisfies the Johnson Criterion for the identification of an armor tank with the use of vertical line structure with four electrically heated lines and three passive lines.
* The thermal guidance target has a special temperature regulator that can regulate temperature contrasts from 0 kelvin to 30 kelvin. Top temperature recommended is 90 degrees celsius. Irreversible damage to the weather resistance material and structure will occur at temperatures higher than 90 degrees celsuis.
* The thermal guidance target resist, to great extend, temperature fluctuations over the beam target area, caused by influences of wind and rain, with the aid of two sided insolation layers.
* The thermal guidance target can be operated using different types of power sources, such as batteries or transformer.
* The thermal guidance target comes with a primary regulated step down transformer 0 to 230 volt and a secondary transformer 0 to 42 volt and conforms to the VDI safety regulations.
* The thermal guidance target can be made to operate according to any other power specifications and requirements.
* The thermal guidance target is very easy to transport. It dolds into the size of 15 x 30 x 120 cm.
* The thermal guidance target is very easy to install. It is tied to a flight frame.
* The thermal guidance target is light. Since it is made mostly of foil.

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