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HELICOPTER INFRARED SIGNATURE

AND

COUNTERMEASURE EVALUATION

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ABSTRACT

H.I.S.A.C.E. (Helicopter Infrared Signature and Countermeasure Evaluation) program is an experimental procedure to investigate infrared signature from a static or flying helicopter and to evaluate it in some defined range.

Results are available in pictures.

The pictures consist of mosaics of 128 by 112 elements.

The effective radiance and temperature of each element (of the target) is depicted by a 3 digit number.

Images are displayed on a high resolution colour monitor and a sophisticated computer program software allows to increase the detail of information.

Results are then processed and quantified to select proper techniques and materials to reduce the infrared signature down to predefined thresholds.

1. INTRODUCTION

H.I.S.A.C.E. (Helicopter Infrared Signature And Countermeasure Evaluation) is a theorethical-experimental technique to evaluate qualitatively and quantitatively the infrared signature of an helicopter.

This technique permits to evaluate and quantify means of infrared suppression once the thresholds of maximum allowable signature are defined.

Such a technique was utilized to evaluate the signature and infrared countermeasures of an AB 412 helicopter (Fig.1-1). Interim results are reported and illustrated on the following pages.

2. ENGINE AND ITS INSTALLATION

To better understand the way of measurements and to appreciate the results it is useful to describe briefly the main features of the AB 412 power plant and its installation. The power plant is a PRATT-WHITNEY PT6T-3B TWIN-PACK delivering 1875 CV.

The engine outlets are parallel to the tail axis and the oil radiators are located just behind them.

In this installation it is necessary to pay particular attention to the rotor-wash phenomenum whose effect is to deviate the hot exhaust gases downwards with the consequence that thermal characteristics of the helicopter are modified.

It is essential to know either the power the engine can supply and the type of its installation because a portion of the power will be converted into infrared energy and this portion will be the main responsible of the infrared signature (Fig.2-1).

However, besides the above mentioned autoemission, other phenomena are responsible for the infrared signature: the most important being the reflections on the helicopter surfaces of autoemitted energy and external sources energy.

3. INFRARED SIGNATURE

3.1 Measuring Instruments

In order to measure the infrared signature we used the following instruments:

1) A calibrated radiometer

2) A spectroradiometer

With the radiometer it is possible to obtain punctual spatial informations on the integral signature (within the spectral response band of the radiometer) while the spectroradiometer can achieve spatial information (with regard to the Instantaneous Field Of View of the instrument) on the spectral and integral infrared signature.

Results, calibration and data elaboration techniques will be shown with reference to the first instrument only.

Fig.3.1-1 shows a flow chart resuming H.I.S.A.C.E. procedure.

3.2 Absolute Calibration of the Radiometer

The calibration procedure developed was meant to establish the relationship between incident infrared energy and output signal.

Such a relationship was parameterized by using proper parameters of the instruments.

Using this relationship it is very easy to appreciate the infrared energy emitted by the target having as inputs the peculiar parameters of the instrument (such as F/n, Thermal Level, Thermal Range) and the distance between the radiometer and the target.

3.3 Ancillary Measurements: $\varepsilon, \varrho, \tau_a, \tau_m$

- Emissivity ε

  The surface emissivity value was obtained by using proper instrumentations in our infrared laboratory. We compared the spectral energy emitted by a reference source (black body) and that emitted by a sample of target material.

  As the emissivity is a function of various quantities (wavelength, angle, temperature and polarization) it is necessary that every single parameter is investigated (Fig.3.3-1).

- Reflectance ϱ

  The directional reflectance values may be extracted from emissivity data by using the following formula: $\varrho_d = 1 - \varepsilon_d$

- Atmospherical transmittance τ_a

  The atmospherical transmittance was obtained by using the computer program LOWTRAN 5 and with an experimental set-up; a black body was positioned near the target source and then its spectral radiance measured and compared with that unaffected by atmospherical absorption.

- Material transmittance τ_m

  The transmittance of material (helicopter window) was obtained by comparing the energy incident on the sample and the energy emitted (by the window).

3.4 Errors

We have now to deal with the accuracy of the measurements. The infrared signature was evaluated with a 8-10% accuracy, this is due to the operating characteristics of the radiometer as well as to spectral changes of emissivity with temperature, angle and transmittance with atmospherical conditions.

4. DATA PROCESSING

4.1 Quantitative Thermal Image Processing

To obtain the infrared signature, the infrared images once recorded on magnetic tape are processed (infrared calibrated data) with proper computer programs employing the absolute calibration values previously obtained .

Data on surface temperature may be obtained from infrared calibrated data by using the value of local emissivity and inverting Planck's formula with the aid of the computer.

4.2 Qualitative Thermal Image Processing

We managed to represent these images in different forms.

- symbolic representation employing up to ten alphanumeric symbols to show isothermal and/or isoradiant areas (Fig.4.2-1).

- Coloured or grey representation: this gives an higher resolution of the punctual information of the radiometer (Figs.4.2-2, -3 and -4).

  This resolution is up to 256 colour tones enabling us to have more information on the behaviour of the emitted infrared radiation and/or on the isothermal curves of some details.

4.2.1 Hardware Instruments

In order to visualize thermal images we used a coloured monitor raster-scan terminal. It is an assembled set built by different films, with different characteristics but with a common structure baseline consisting of an Image Memory (I.M.), an output monitor and a Video Interface (V.I.).

The I.M. is a matrix of elements on a square grid, each of them is a digital pixel.

The number of these pixels may vary from a minimum of 256 x 256 up to a maximum of 1024 x 1024. Every element as above mentioned is a digital information, i.e. it may vary from 0 to $(2^n - 1)$, if we assume I.M. as a set of matrices; of a single bit, "n" is the number of such matrices, also called memory surfaces.

Usually this kind of assembly allows to add other memory surfaces up to a maximum. V.I. is an interface that reads numerical data from I.M., and drives the monitor through a D.A. converter.

V.I. also drives a wired logic with which it is possible to relay the D.A. converter.

It is easy to connect a grey-tone scale to the I.M. numerical values according to a linear logarithmic or any other kind of law.

4.2.2 Software Instruments

Data processing was made through CIPS system (Conversational Image Processing System) designed and developed in CNUCE (An Institute of National Council of Research).

Such a system allows to process iterative numerical matrices and has a computer program library.

The main characteristics of the CIPS system are:

1) Efficiency, in processing data: ease in recalling and elaborating data and results imaging.

2) Ease in adding new functions to best help the last user.

3) Processed data safety preventing loss of information due to erroneous operation.

4) Ease of operation.

To obtain the above features, series of computer programs dealing with service mathemathycal, statistical and geometrical functions were developed.

5. SUPPRESSION PHILOSOPHIES

In order to vary the infrared signature autoemitted by a solid source we may:

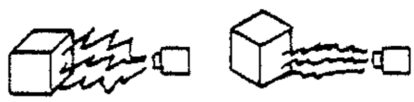
a) Vary its temperature

$$T \rightarrow T$$

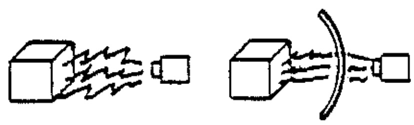
b) Vary its emissivity

$$\varepsilon \rightarrow \varepsilon$$

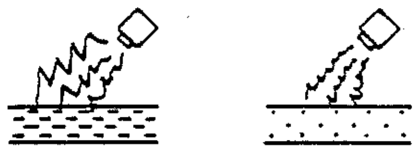
c) Vary the angle of emission



d) Shield it



e) Vary its thermal properties



The ways to obtain the above conditions a), b), c), d) and e) are:

1) Film cooling of hot metal parts. This point is a particular means of suppression that we'll not treat here.

2) Mechanical or chemical treatments

3) Coatings

4) Paints

5) Insulation

6) Shields

Let's examine one by one except the first one:

2) *With a mechanical treatment* it is possible to vary the surface geometry achieving the control in the direction of emitted or absorbed radiation. By combining mechanical and chemical treatments we may *obtain a quantitative directional* control upon the emitted (auto-emitted and reflected) energy.

These kinds of treatment may be difficult and expensive to obtain but they are very effective and almost uninfluential on the weight of the emitter.

3) With proper coatings we may obtain the best results on the control of ε, ϱ (apparent temperature) and also on the actual temperature.

These coatings may be easy to apply, have good mechanical characteristics and remain stable at high temperatures in different atmospherical conditions too.

There is no influence on weight while they are cheap.

The efficiency in the directional control of ε and ϱ can be good but not so deep as 2).

4) Paints are particularly recommended to control the infrared signature in ambient conditions.

Their use is suggested when trying to control the visible range.

As well, it is infact possible to obtain very high emissivity values ($\varepsilon \simeq 0.9$) mantaining good characteristics in the visible range.

These paints suffer from thermal *degradation, U.V. and atmospheri*cal pollution but usually the degradation is limited to their optical absorption coefficient.

5) Insulation is used when wishing to avoid heat transfer.

By insulating a surface, with small thickness of thermal shields, it is possible to lower its temperature and hence the quantity of infrared emitted energy.

Adding this technology to the others such as:

1) Coatings

2) Paints

3) Mechanical and chemical treatments

we may lower both the emitted and reflected energy.

The efficiency of the treatment is very high, often quite easy to apply, cheap and light weighted.

For high temperatures we may suggest insulation as this does not create any thermal degradation problems.

You have only to take care that the insulation is not exposed to exhaust gas pollution.

6) The shielding of hot surface is the surest and cheapest way to obtain a good suppression of infrared radiation and/or to control the direction of the emission.

The shielding can be built with low specific weight material such as:

1) Light alloys

2) Various plastic materials

3) Rubber materials

4) Syntetic materials

and even with high specific weight materials such as:

1) Steel

2) Copper alloys

This kind of choice is due to their particular mechanical and chemical--physical characteristics.

The shielding may indeed be a combination of various materials so as to improve the infrared suppression efficiency.

The choice of the kind of infrared suppressor is dictated both by customer requirements and by the aircraft installation interface.

6. ACKNOWLEDGMENT

A particular thank is addressed to Mr. Bettarini (C.N.U.C.E.) for his help in computer elaboration.

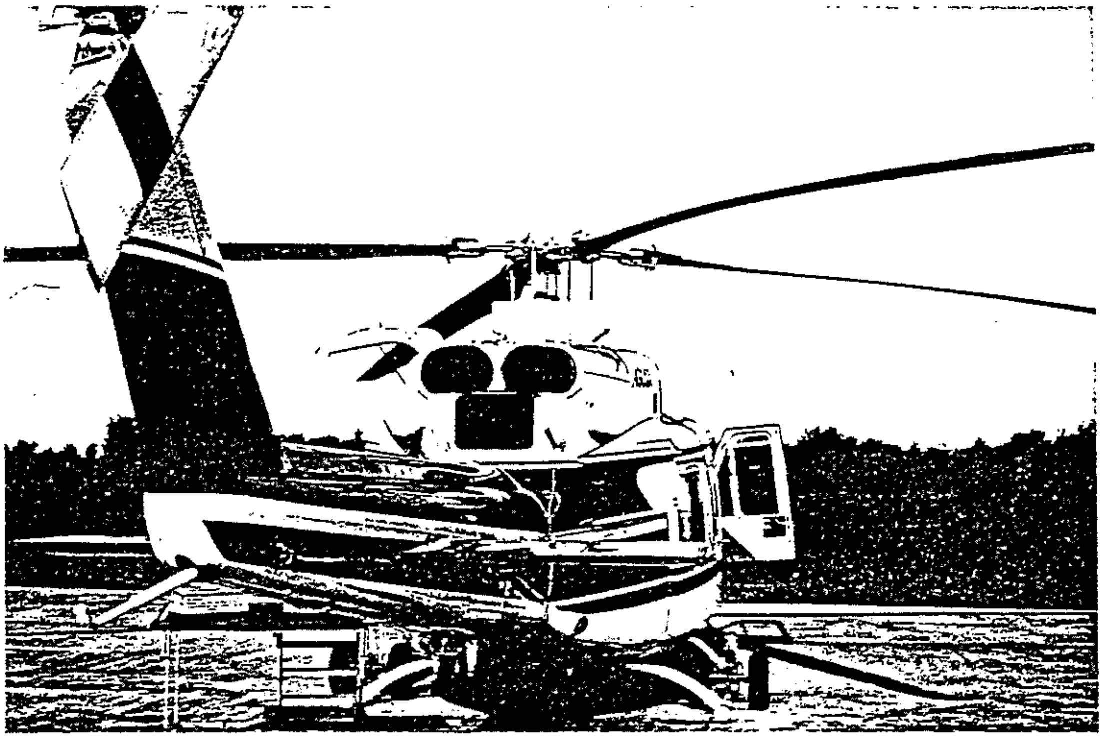


Fig. 1-1 AB 412 Helicopter

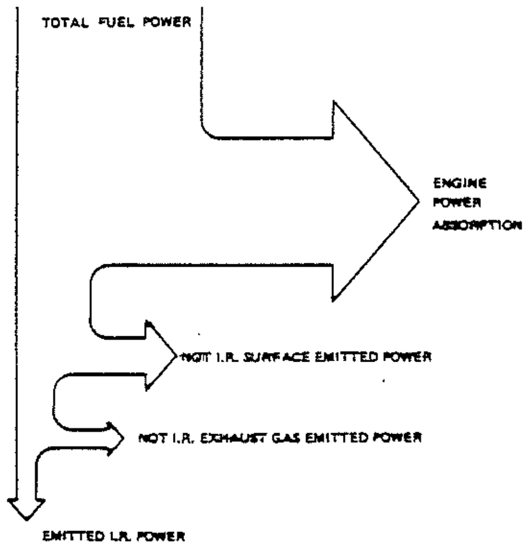


Fig. 2-1 Power Issue

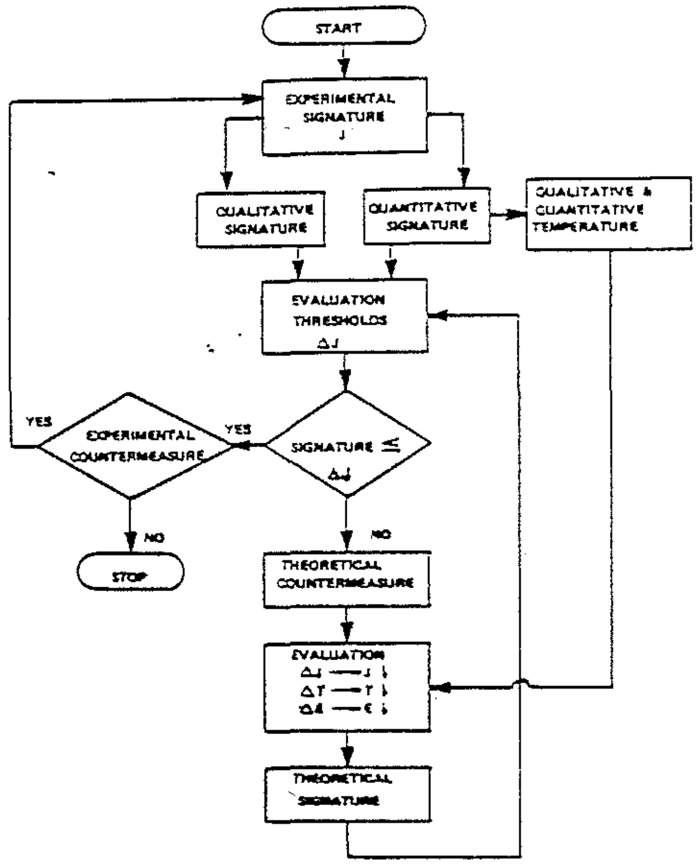


Fig. 3.1-1
H.I.S.A.C.E. Flow Chart

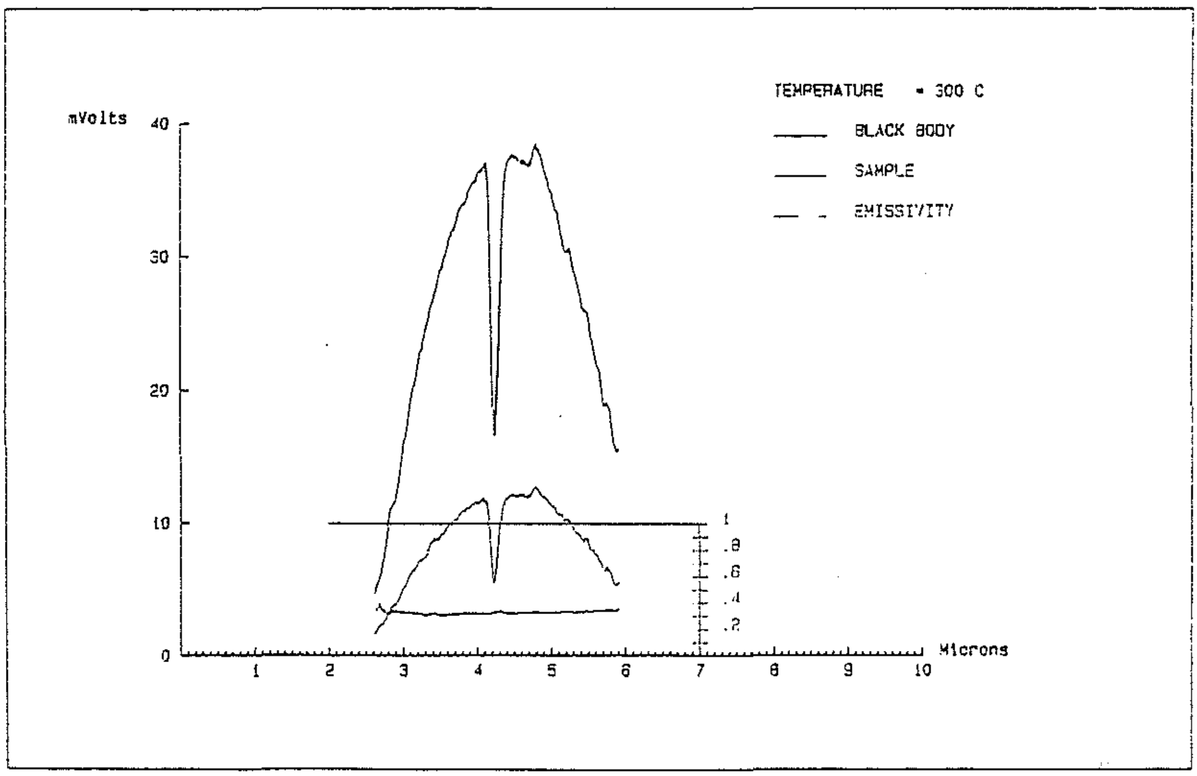


Fig. 3.3.-1 Spectral Emissivity

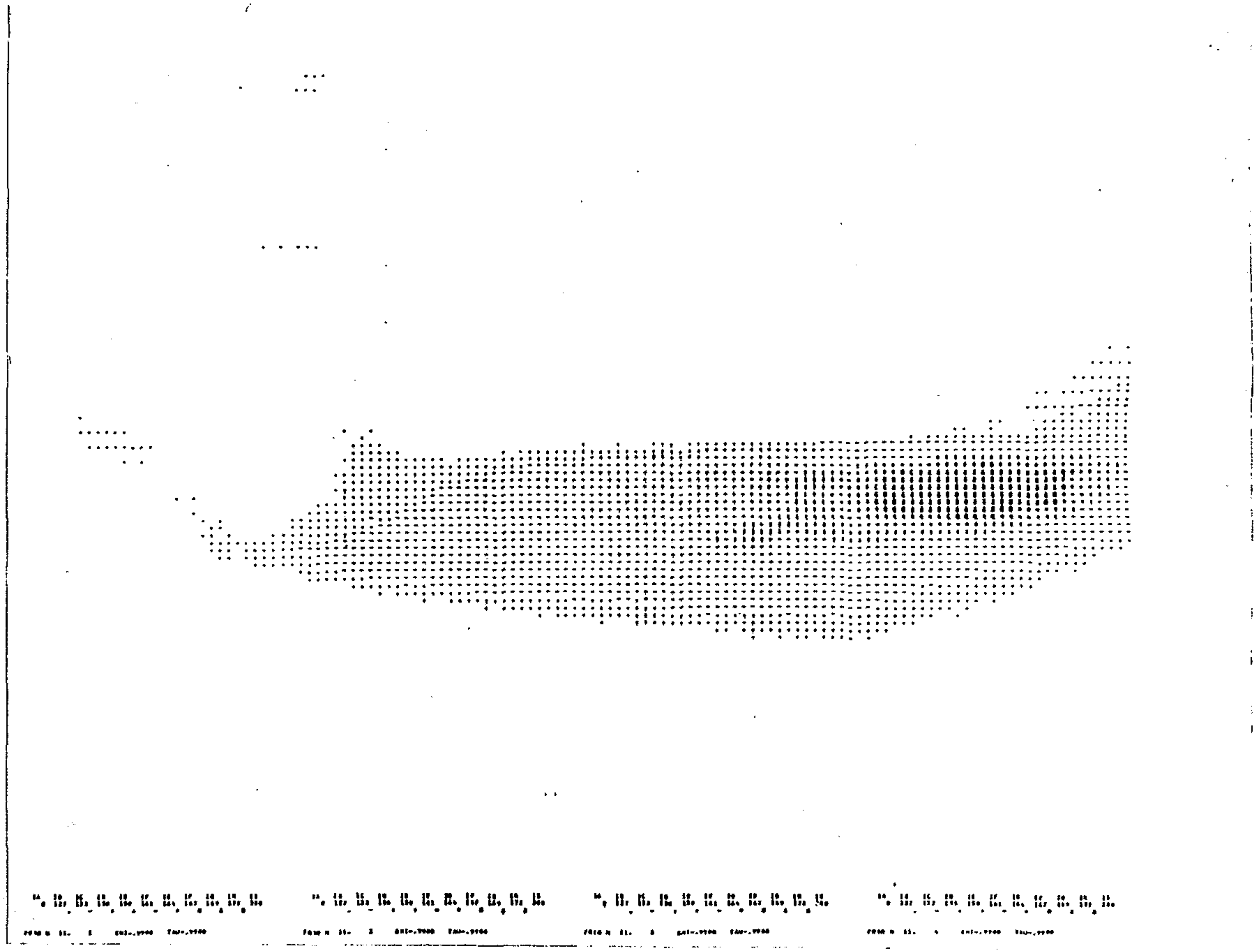
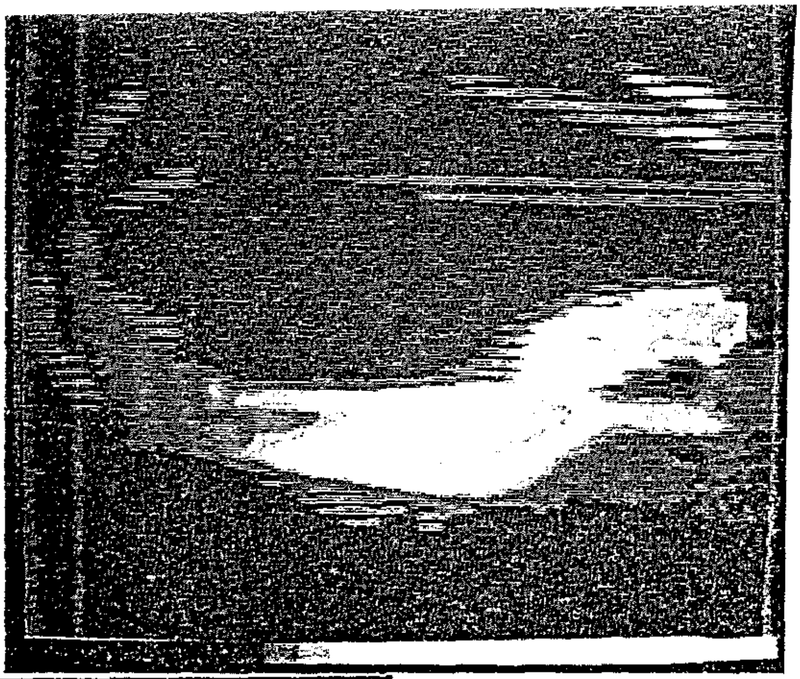


Fig. 4.2-1 Isoradiant Computer Printout

Fig. 4.2-2 Qualitative Thermal Image Processing

Original in Grey Tones



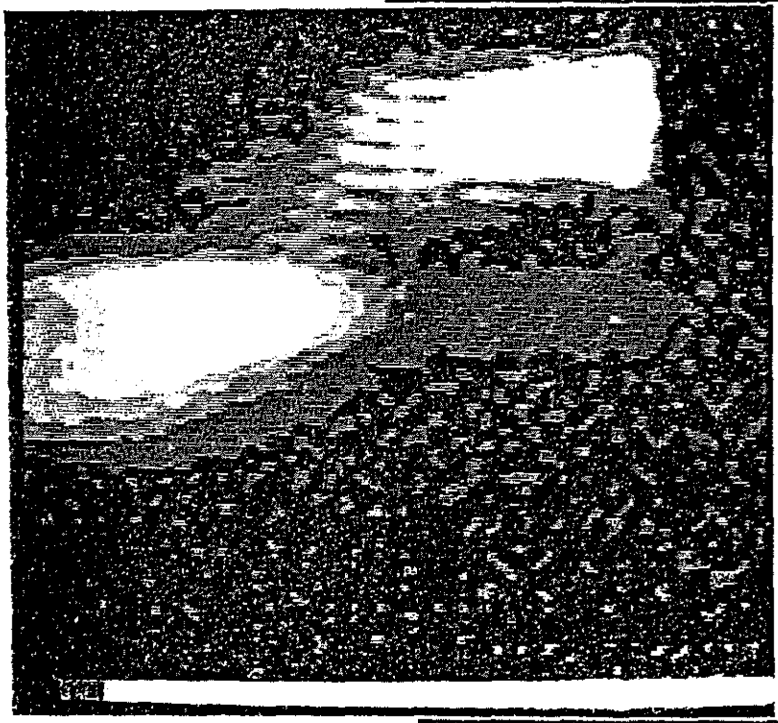


Fig. 4.2-3
Magnification of the above

Fig. 4.2-4
Magnification of the above