INFRA-RED DEVICES FOR MILITARY USE

by

C. S. Rao, V. Ramakrishna Rao and K. R. Mehta

Instruments Research and Development Establishment, Dehra Dun

ABSTRACT

The importance of infra-red devices for military purposes, and the need for research & development in this branch of instrumentation are described in this paper.

Introduction

Secret operations during night have always played a major role in military strategy. To aid this, various steps were taken from time to time. The best and the latest, however, appear to be the Infra-red (I.R.) devices. During and since the World War II, great strides were made in the development of the devices for the three wings of the Armed Forces. They were used for signalling, guiding beacons for ships and aircraft, homing guided missiles, night driving of convoys, and for night observation by snipers, gun crew and tanks without giving away their position.

All military targets are copious emitters of I.R. radiation and so are susceptible to detection by I.R. techniques. Besides being simpler, smaller and less expensive than radar, they are, in addition, passive and difficult to jam, and so are supplementing and gradually replacing radar.

I.R. Spectrum

The normal and un-aided human eye is sensitive only to a small part 0·4 to 0·7 micron of the spectrum. On either side of the visible region wide ranges of invisible light, called the ultraviolet and the Infra-red, are available. The I.R. part of the spectrum is very extensive and can be conventionally divided into a few manageable regions as follows:—

Near I.R.	0·8 μ to 1·3 μ.
Intermediate I.R.	1·3 microns to 7 microns.
Far I.R.	7 microns to 13 microns.
Very far I.R.	beyond 13 microns.

Methods of detection

The methods of detection in these different regions depend upon a number of physical phenomena, primarily utilizing the thermal effects of the I.R. radiation. The effects are (*i*) thermoelectric (generation of *e.m.f.* in a bimetallic thermal junction due to temperature difference), (*ii*) bolometric (variation of resistance with temperature), (*iii*) Pneumatic (variation of pressure with temperature) etc. The region up to 1·2 microns can be detected photographically using special dyes of the cyanine group like krypto-cyanine and neo-cyanine

This method is used in I.R. photography which gives clearer pictures through haze and mist than normal photography. Aerial photography and long distance ground reconnaissance are now turning more and more towards I.R. for this reason.

The same region is also detected with the image converter-tubes. These consist of a photo-emissive surface, Ag-O-Cs and a phosphorescent surface ZnS in a vacuum tube. The photoelectrons released from the photo-emissive surface by the incident I.R. radiation are accelerated towards the phosphorescent surface by electrical voltages and produce greenish phosphorescence on the ZnS screen. The result is a visible image of the target for observation by the human eye.

Other physical effects that are used in the detection of I.R. radiation are the photo-conductive and photo-voltaic. The former depends on the fact that conduction electrons are released from special surfaces like lead sulphide when I.R. light is incident upon it. The latter depends on the development of potential difference between two layers of conducting materials, in between which a photosensitive barrier of high resistance is deposited, when exposd to I.R. radiation. The useful ranges for these two types of detectors are up to 5 microns. Their sensitivity and response are further increased by operating them at low temperatures.

Most of the above methods of detection involve electrical quantities in the micro-range. This needs considerable amplification for presenting the data in an observable manner. Suitable electronic equipment for rectification and amplification, therefore, form integral parts of the detection systems.

Detection methods are available for self radiant objects. As already mentioned, all military objects are copious emitters of I.R. radiation. The range of this radiation is in the intermediate and far I.R. All natural bodies emit radiations depending upon their temperatures. The approximate radiation formula $\lambda_{m \; in \; microns} = \frac{2897}{T^{\circ} \; Absolute}$ determines the region of peak emission (λ_m). Human bodies, auto-engines etc. can be detected and photographed with suitable techniques. Two such techniques are the evaporograph and thermograph, the former used for single targets and the latter for scanning wide areas like an air-port. In the evaporograph the heat picture is formed by focussing the incident I.R. radiation on a thin membrane at the back of which is given an oil coating. The heat radiation causes the oil to evaporate and changes point-to-point thickness of the film. White light projected on this pattern produces interference colour picture which can be observed directly or photographed. However, in a thermograph the principle used is different. It obtains the thermal image over a thermistor bolometer detector, the electrical output from which is amplified and is made to modulate the light from a lamp. This is scanned across a photographic film which is in synchronism with the initial pick-up scanning system and produces a picture in a manner similar to the wire-photos used in newspapers. If a thermistor bolometer is chosen so that its sensitivity is uniform over a wide range of I.R. (6 to 10 microns), fairly large scenes like an air-field can be scanned and their thermograph pictures obtained.

The non-image forming type of detectors like the photo-conductive cells etc., after suitable amplification of the power, present the data on electronic devices via a cathode-ray tube or a servo-mechanism with a recorder. These methods are particularly used for the detection of rockets and satellites. Sputnik I was always detected as it passed over Boston, Massachusets (USA), both by day and night.

Radiation sources and filters

The basic components of any I.R. device can be represented by means of the following block-diagram:—

I.R. source	—	Filter	—	Optical system	—	Detector	—	Data presentation

The sources of radiant energy in the I.R. are varied. A tungsten filament lamp at a colour temperature of 2848°K is used for I.R. emission upto 1·3 microns. The tungsten filament lamp and xenon lamp are mostly relied upon to provide artificial I.R. radiation required in special devices. Otherwise most other targets are self radiant and can be detected by their own characteristic I.R. radiations.

All artificial sources of I.R. radiation also emit visible radiation, hence the need for filters to cut-off the visible light. Chemical filters, interference filters and specially processed glass filters are in vogue depending on their region of interest. In addition, space filtering techniques and electronic filtering techniques have to be incorporated to attain the necessary contrast between the target and the background.

Optical systems

The optical system used in I.R. devices consist of lenses, prisms, mirrors and window materials. Depending upon the region of interest, special materials have to be chosen for making the above components. Some typical I.R. transmitting materials useful in various regions are given below:—

1. Conventional glass suitable up to 1·3 μ.
2. Crystal quartz suitable up to 4·5 μ.
3. Sapphire suitable up to 6·5 μ.
4. Calcium Fluoride suitable up to 10 μ.
5. Sodium chloride suitable up to 25 μ.
6. KRS—5 suitable up to 40 μ.
7. Cesium bromide suitable up to 50 μ.

The front surface mirrors generally used in I.R. instrumentation are made by evaporating silver or aluminium. Once the right material is chosen, the considerations for optical design are practically the same as in the conventional optics.

Broad details on detectors and data presentation are given earlier. As in the usual electronic circuits, a variety of noise factors in the detectors are to be taken into account in the design considerations.

Conclusion

The brief and by no means all comprehensive description given above is adequate to show the wide variety of investigations necessary for the development of I.R. devices. The strategic importance of the I.R. devices cannot be over-emphasised. This has been recognised early in the advanced countries resulting in sealing up of all the technical know-how under a classified category. Even for the development of simple devices familiarity and grasp of a wide variety of physical phenomena, laws and techniques are essential. There does not appear to be a possibility of peace-meal development in this branch of instrumentation. For the rapid progress in I.R. instrumentation, a bold planning of comprehensive nature is, therefore, essential.