ASPECTS OF THERMOGRAPHY AS APPLIED TO THE SUGAR INDUSTRY

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Abstract

The principle and operation of a total radiation pyrometer, commercially known as Thermovision, is described. The pyrometer is used, among other applications, for measuring the temperature above ambient of electrical components under load. A photograph of the "hot spot" known as a thermogram, can also be obtained.

1. *Introduction*

Everything around us gives off heat in the form of infra-red radiation. Recently, a commercial system known as Thermovision has been developed by a Swedish firm to convert this radiation into electrical signals which are in turn used to produce a live thermal picture on a cathode ray tube. Any temperature variation within the field of vision of the camera is clearly shown and can be measured and photographed using a special camera attachment. If used correctly, this system becomes a very powerful preventive maintenance tool.

2. *Principles of operation of the equipment*

The electro-magnetic spectrum is divided, more or less arbitrarily, into a number of wavelength regions called bands, distinguished by the method utilized to produce and detect the radiation. (See Fig. 1).

Thermography makes use of the infra-red spectral band which is further sub-divided into the "near infra-red" (0,75–3 μm), the "middle infra-red" (3–6 μm), the "far infra-red" (6–15 μm) and the "extreme infra-red" (15–1 000 μm).

Thermovision utilizes the middle infra-red, or, more specifically, the 2 to 5 μm band. It measures the total energy radiated by a body in that wavelength band in accordance with the Stefan-Boltzmann Law.

This expressed quantitatively states that:

$$W = \alpha \sigma_0 T^4$$

where W = Total radiated energy per unit area (Jm^{-2})

T = Absolute temperature (°K)

σ_0 = The Stefan-Boltzmann constant ($5{,}67 \times 10^{-8}$ $W\ m^{-2}\ K^{-4}$)

α = a non-dimensional factor known as total emissivity and defined as the relationship between the radiation of the relevant surface and that of a black body at the same temperature.

3. *The equipment*

The equipment comprises two basic units — a camera which is focused onto the item to be studied and a television-like display screen with all the relevant controls (Fig. 2).

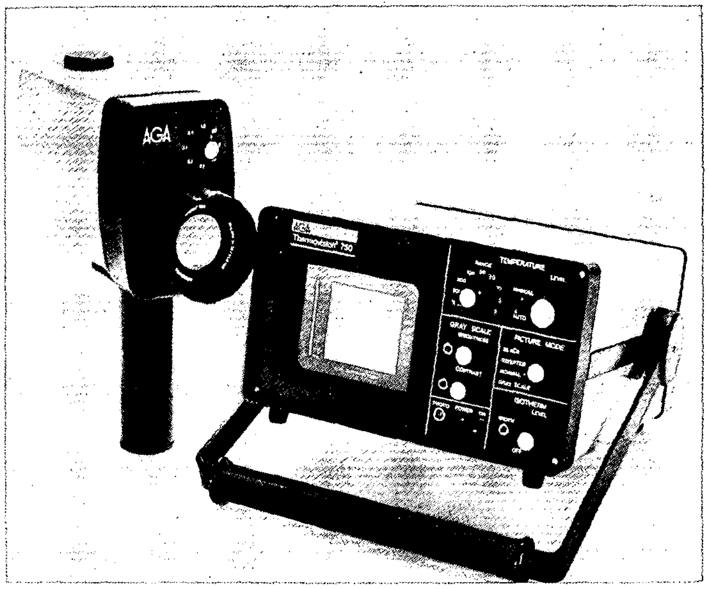

FIGURE 2 Camera and Display Unit.

The functional block diagram of the system is shown in Fig. 3. The energy path enters the camera through the front lens, is refracted through the vertical and horizontal scanning prisms and focused on to an indium antimony solid state detector. The InSb crystal is constructed integrally with a Dewar Flask which serves both as a container for the coolant (liquid nitrogen) and as a vacuum envelope for the detector element.

Fig. 4 shows the optical paths within the camera unit resulting from different positions of the scanning prisms.

The camera utilizes selectively reduced apertures to obtain its temperature of −20°C to +900°C. An insertion of a "grey" filter in the optical path extends this range to 2 000°C.

The signal derived from the camera is amplified and used to modulate the intensity of the electron beam of the TV-monitor

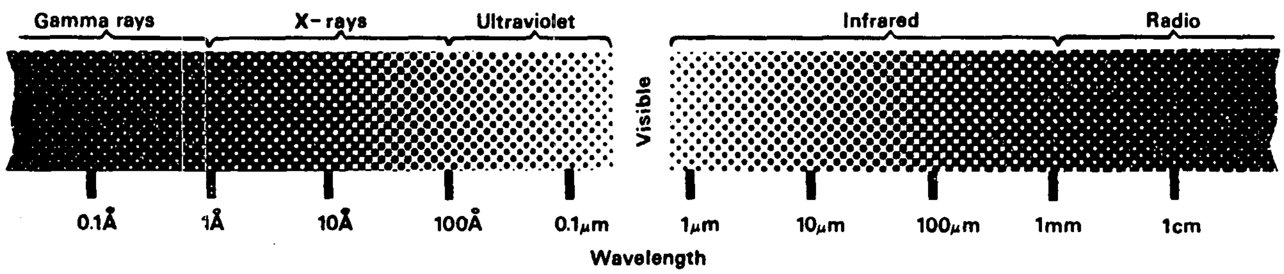

FIGURE 1 The Electromagnetic Spectrum.

type picture tube in the display unit. The electron beam sweeps across the screen of the monitor tube in synchronism with the camera scanning-optics, under control of the trigger pulses derived from the camera. This produces on the display screen a thermal picture of the object being scanned. (Figs. 5 and 6).

When quantitative temperature measurements are required, a selected amount of the infra-red radiation focused on the detector in the camera can be marked electronically to produce isothermal contours on the display screen. Whenever the detector video signal level corresponds to the preset isothermal level selected by the operator, the electron beam of the picture tube is automatically switched to maximum intensity. This causes all areas in the thermal picture having the selected temperature level to be delineated in saturated white. The isothermal contours this produces can be used to measure the exact amount of temperature variation existing between details of the thermal image of an object.

Due to the highly nonlinear nature of the temperature/radiation characteristics of the IR detector, the actual magnitude of the selected temperature span is a nonlinear function of the absolute temperature level. Because of this the instrument is not calibrated directly in terms of temperature, except for a limited range which includes the temperature of the human body. Instead, a set of simple calibration curves is used to obtain the actual temperatures. The isothermal contours can be photographed in colour by means of a special accessory for automatically inserting various coloured filters between the display screen and a standard photographic camera loaded with colour film. For each colour used a different contour level is selected and superimposition then produces a "colour thermogram" consisting of the various isothermal contours shown in the colours of the filters. This technique is used to show up complex surface temperature patterns on objects, clearly and dramatically, in a single thermogram. Colour images can also be generated continuously on a special colour TV monitor.

Applications

The range of applications for "real time thermography" has only begun to be investigated. The list includes medical diagnosis, searching for people lost at sea and on land, heat pollution detection of waterways and coastal areas, industrial process supervision, location of faulty insulation in buildings and plant, checking linings in smelting furnaces, ladles, converters and kilns and detection of "hot spots" in electrical circuitry. It is this last application that is proving very useful in the sugar industry.

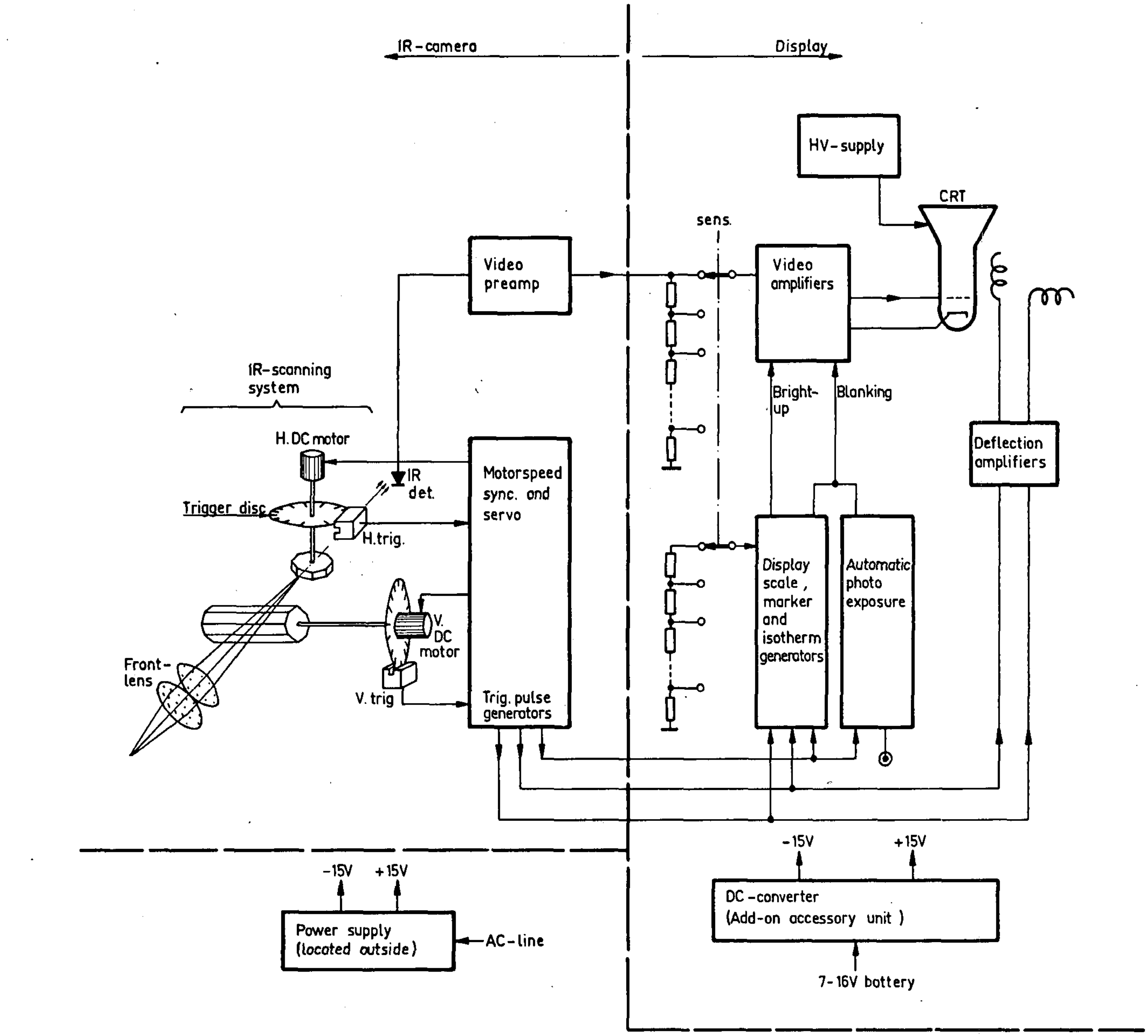

FIGURE 3 System Functional Block Diagram.

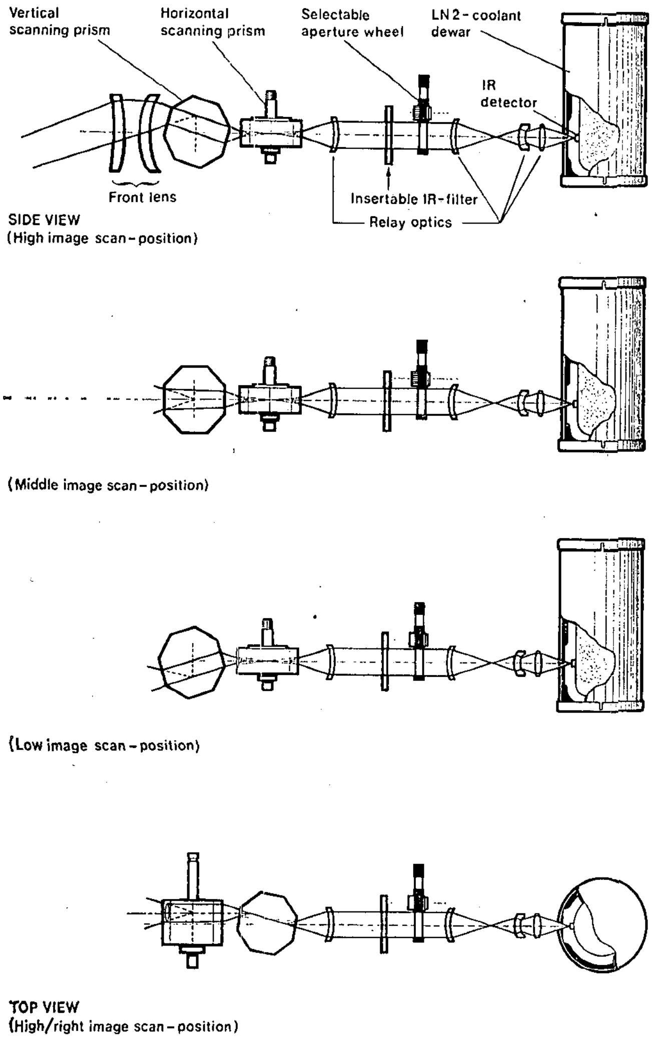

FIGURE 4 Diagram showing refractive prism-scanning optical paths within the camera unit, resulting from different positions of the scanning prisms.

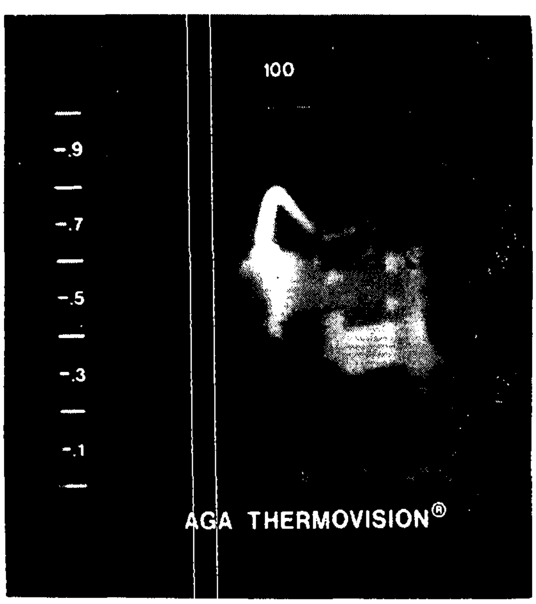

FIGURE 5 Thermogram showing a contactor with a faulty connection.

On the low voltage side bad connections or faulty contact points can be quickly and easily detected on such items as breakers, O.C.B.'s, contactors, thermal overloads, relays, etc.

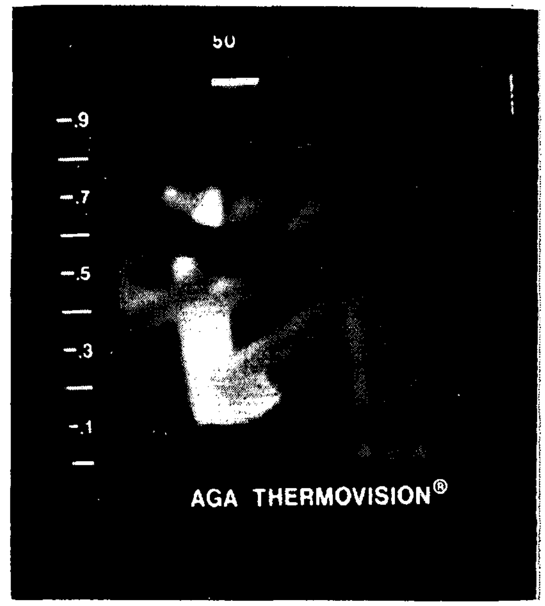

FIGURE 6 Thermogram showing a faulty busbar connection. The actual connection is not visible because the busbar chamber could not be opened with busbars live.

On the high voltage side, where covers cannot be taken off, inspection of the outside of the cable boxes, switchgear and busbar chamber can reveal, and has revealed, trouble areas which would otherwise have caused damage amounting to thousands of rands. Where outdoor substations are used, the inspection is more accurate since all the potential trouble spots are open for direct scanning.

The equipment is sensitive enough to detect temperature differences of as little as 0,2°C. This feature allows an experienced operator to detect some types of motor faults (e.g. bad connections on one of the phases) when inspecting the equipment at the L.V. sub-station).

Preventive maintenance

Regular inspection of some of the South African sugar mills over a period of years has shown thermography to be a very useful preventive maintenance tool in this industry.

The thermographic survey of all the electrical equipment should be carried out at about six monthly intervals. The best time for these appears to be November (about two months before yearly shut-down) and June-July. This frequency of inspection has the following advantages:

(1) Minimisation of the possibility of shut-downs due to electrical faults.

(2) Detection of faults before equipment is irreparably damaged.

(3) Provision of information for maintenance scheduling.

(4) It is no longer necessary to "tighten up every connection" and thus unintentionally introduce new faults.

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