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Passive Infrared Technology for Security Systems and Law Enforcement

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I N T R O D U C T I O N

Passive infrared systems are detecting the minute difference in thermal radiation between the surface of the human body and the background. Temperature difference as low as 1 °C can be detected. As background temperature vary as well as emissivity factors, the detection probability is very high with almost no possibility to overcome such systems.

The self-radiation of the human body is weak and far away from visible light and the commonly known infrared of LED's. (Fig. 1)

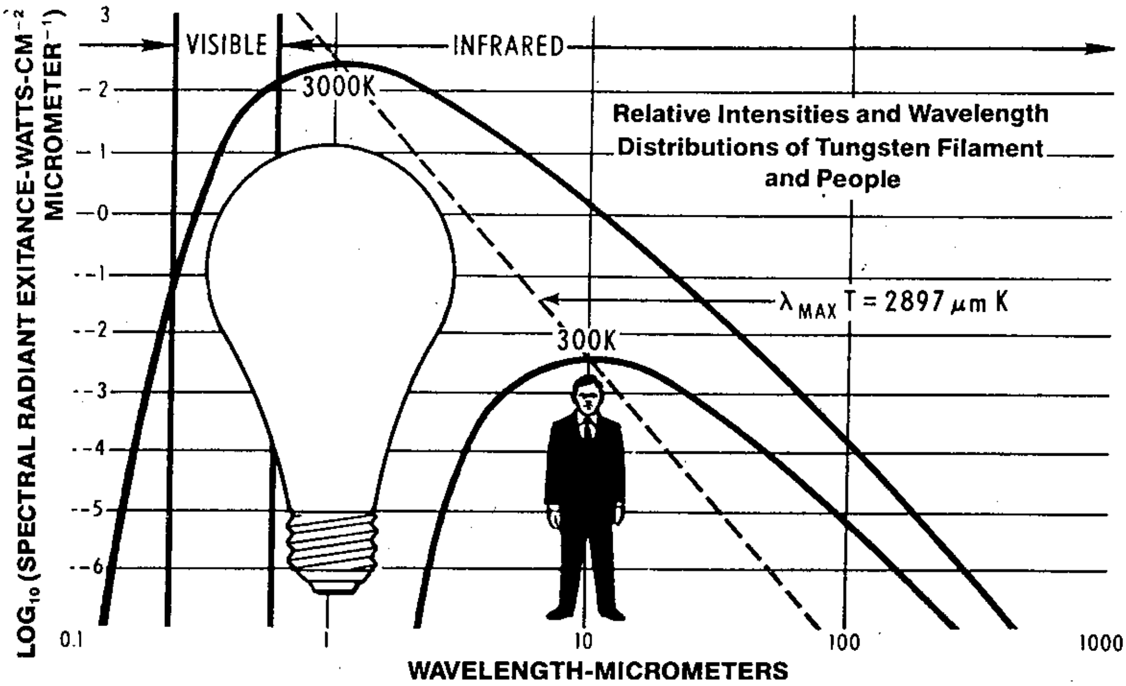

Fig. 1

Consequently, detector cells (or transducers) used are not just ordinary photocells, as those would not be able to detect the infrared radiation in the 7 to 14 μ (microns) range. Instead, so called thermal detectors are used.

A thermal detector is made of an absorber, absorbing the incoming radiation and converting it to thermal energy, i.e. a temperature increase. (Fig. 2)

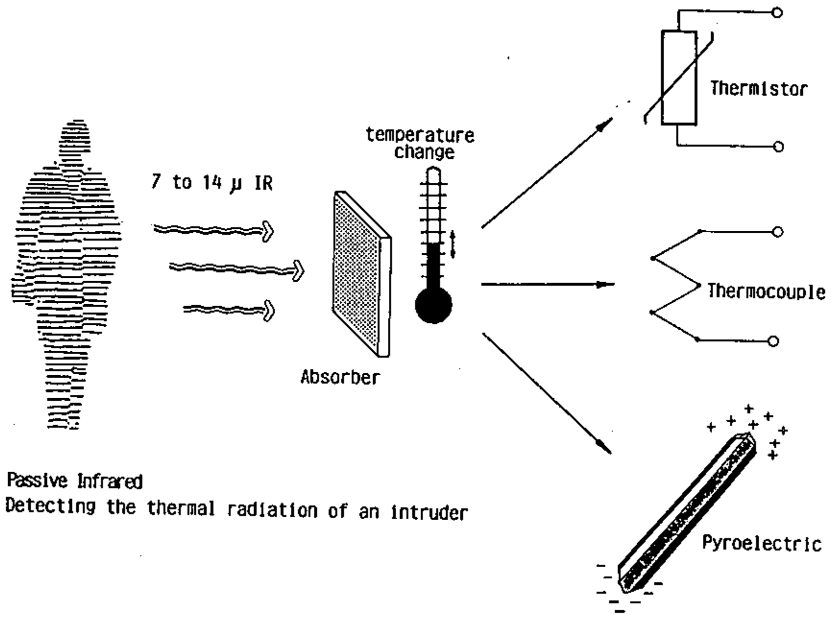

Fig. 2

This temperature increase is then electrically sensed by means of ordinary temperature sensors such as thermistors or thermocouples (thermopiles) or, more recently, by pyroelectric crystals.

THE PYROELECTRIC EFFECT

Some inherently polarized materials (electrets) develop an electrical charge on their surface when exposed to a temperature change. This is the so-called pyroelectric effect and it is related and very similar to the more commonly known piezoelectric effect used in sound and pressure transducers.

Materials like PVF plastic films and Lead-Zirconate-Titinate (PZT) ceramics are both piezoelectric and pyroelectric. Although cheap and widely used in sound transducers, they do not have the required senitivity and stability for infrared detection in intruder alarms . And of course, such detectors would be very microphonic.

A much better material was found in **Lithium Tantalate,** a nonmicrophonic, stable crystalline material similar to quartz. **Lithium Tantalate** crystals are grown and processed as semiconductor materials like silicon. (Fig. 3)

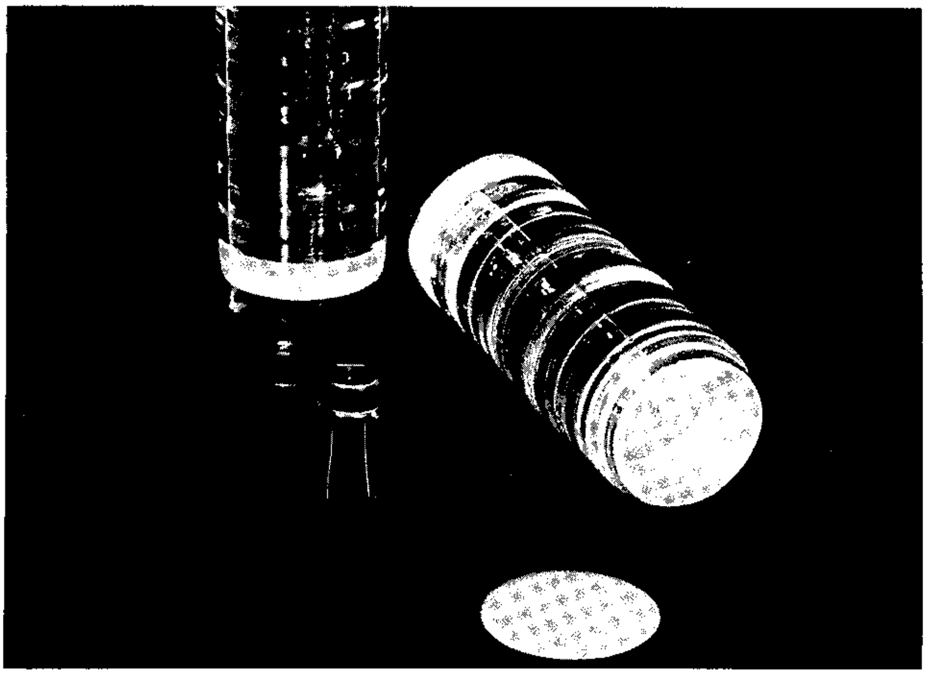

Fig. 3

Boules of single-crystal Lithium Tantalate with cut wafer and detector (TO-5 can) to show size. Wafer is 0.23mm (0.009 inch) thick before lapping, polishing, electroding and dicing.

Although excellent in performance, **Lithium Tantalate detectors** have an extremely high electrical impedance. This is a severe complication in making such detectors. As a consequence, a special hybrid impedance converter must be employed. Low leakage, low noise field effect transistors and high megohm thick film chip resistors with 10^{11} Ohms have been developed for this application

DETECTOR DESIGN

In a practical detector, a thin wafer of **Lithium Tantalate** is used with electrodes on both faces. When the wafer is heated by incident radiation, an electrical charge is created on opposite faces and collected by the electrodes.

The crystal wafer is suspended on special wire loops to restrict substrate heat flow as well as to reduce microphony. (Fig. 4)

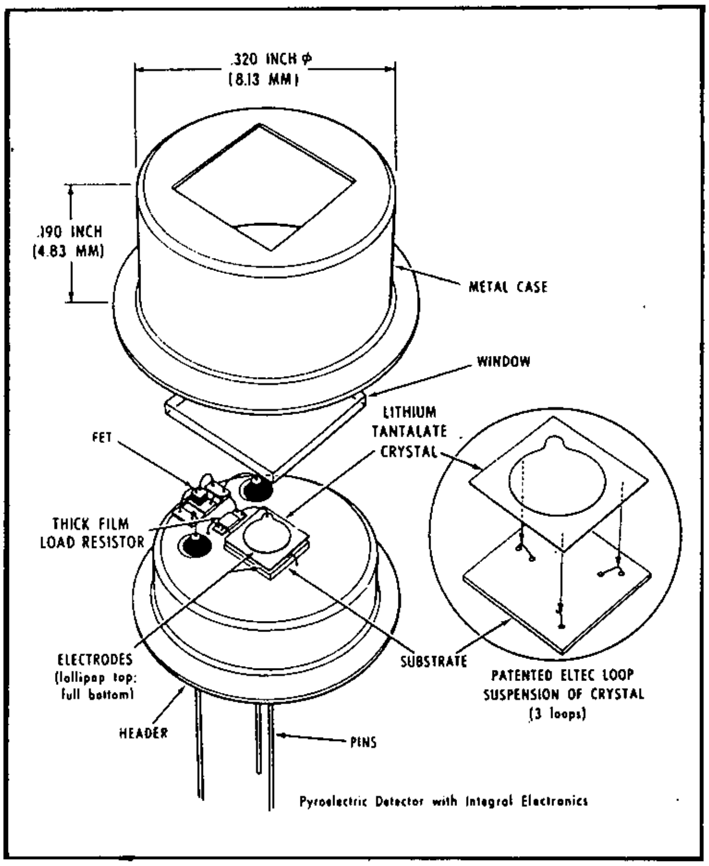

Fig. 4

In the most common case, a "voltage mode" amplifier in form of a source-follower circuit is used as an impedance converter. (Fig. 5)

This circuit is integrated into the detector package. When higher output signals are required, it is possible to integrate complete amplifier and signal conditioning circuits.

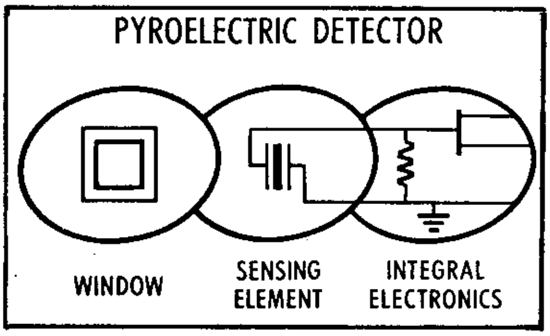

Fig. 5

The complete detector assembly is mounted into a TO-5 transistor housing, hermetically sealed and filled with an innert gas. A coated germanium or silicon window (optical filter) is provided with bandpass characteristics from 7 to 14 microns wavelength. The filter is made electrically conductive and provides complete electromagnetic shielding of the very sensitive detector assembly. (Fig. 6)

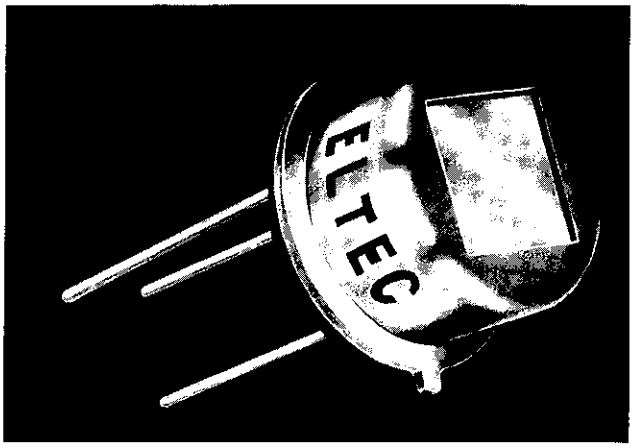

Fig. 6

OPTICS

The infrared detector in an intruder alarm device cannot be used without optics. Such optics, focussing onto one or more narrow zones where the intruder is expected to pass, provide not only a strong signal intensification in the order of 1 : 50, but also the modulation of the signal when the intruder enters and leaves the zones. A number between 1 and 20 such finger-like zones are typical for volumetric infrared protection. (Fig. 7)

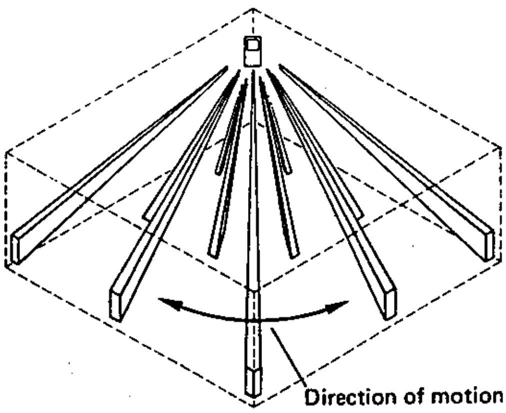

Fig. 7

Ordinary glass and plastics do not transmit the long wavelength infrared in the 7 to 14 microns range. Metallized plastic mirrors and thin plastic fresnel lenses have been found to be practical and inexpensive. The mirrors and lenses are usually segmented, with each segment focussing in a different direction and determining one zone.

The importance of powerful optics and specific design criteria are stressed out in reference ELTEC data 104.

DUAL DETECTORS

The breakthrough of passive infrared intruder alarms came with the introduction of the dual detector. Single element detectors respond to any change of infrared radiation in the environment such as caused by sunlight, air conditioning systems, heaters etc. and lead to unacceptable false alarm rates.

The dual or differential detector provides an analog addition of the signals of two detector cells with opposite polarities. Ambient signals impinging on both cells are cancelled and do not result in an output signal. However, in combination with the commonly used segmented mirrors or lenses, the two cells do not have identical fields of view and a moving intruder creates a sequence of positive and negative signal pulses. In other words, each zone of the instrument is split into a positive and into a negative zone. (Fig. 8)

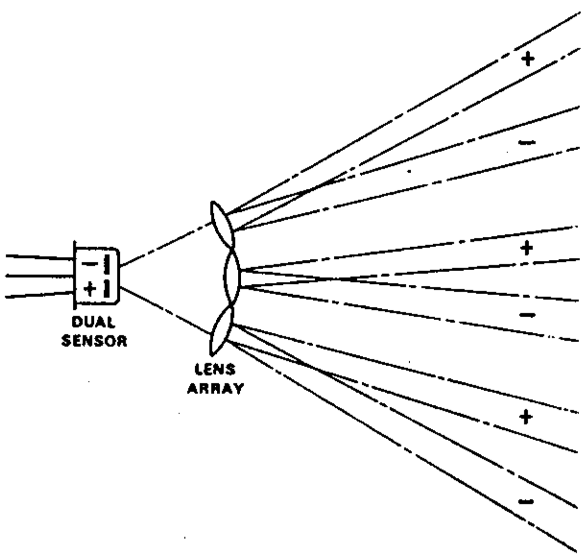

Fig. 8

DETECTOR ARRAYS

Applications in high risk security systems such as outdoor (perimeter) protection need an even better discrimination between real intruders and environmental disturbancies. A wide range of more sophisticated detectors has been developed for these applications. Best results are obtained when the signals of a number of adjacent detector cells are compared to each other with appropriate signal discriminators or even a microprocessor.

Such detector arrays are produced with 2 to 10 cells each having a separate signal output. Figure 9 shows a 8 element array used in surveillance systems. It includes complete signal amplification for each cell, all integrated into one standard dual-in-line IC package. As detector cells are produced in very large quantities for commercial security systems, such arrays can be manufactured relatively economically and with outstanding performance and reliability. (Fig. 9)

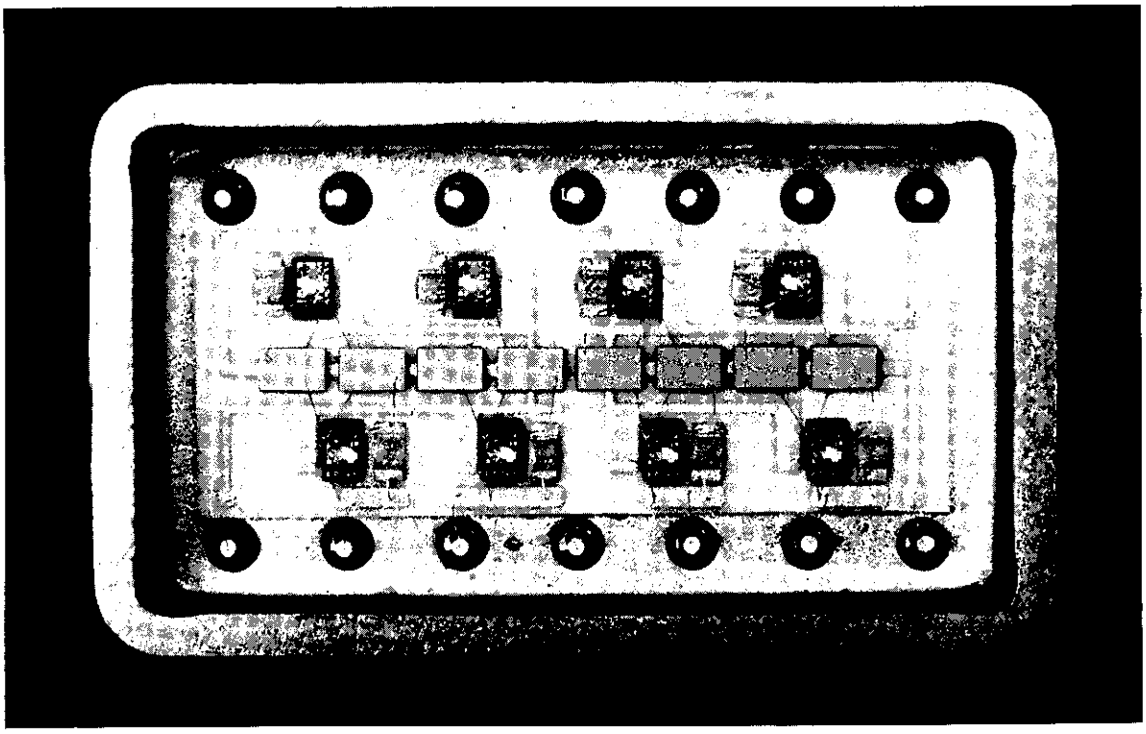

Fig. 9

ELECTRONIC CIRCUITS

Electronics used in conjunction with pyroelectric detectors need careful considerations because an alarm is triggered on a few or even only on one sudden change in the detector signal level. Consequently, false alarms can be caused by a large variety of component failures, weak solder joints and electromagnetic interference.

The basic circuit shown in Fig. 10 has a two stage voltage regulator to smooth down changes in the power supply to a fraction of a millivolt for the detector supply. A two stage signal amplifier is provided with a gain of 1000 to 5000 (60 to 75 db) and bandpass characteristics in the low frequency range of typically 0.4 to 4 Hz. This bandpass is adapted to the detector signals created when an intruder is slowly walking through the zones. Signal discrimination is made with a single comparator in its simplest form, detecting a signal pulse exceeding a certain level. Reliability can be improved when positive and negative excursions of the signal are detected and an alarm only triggered when a minimum number of signal pulses occur within a predetermined time span. (Fig. 10)

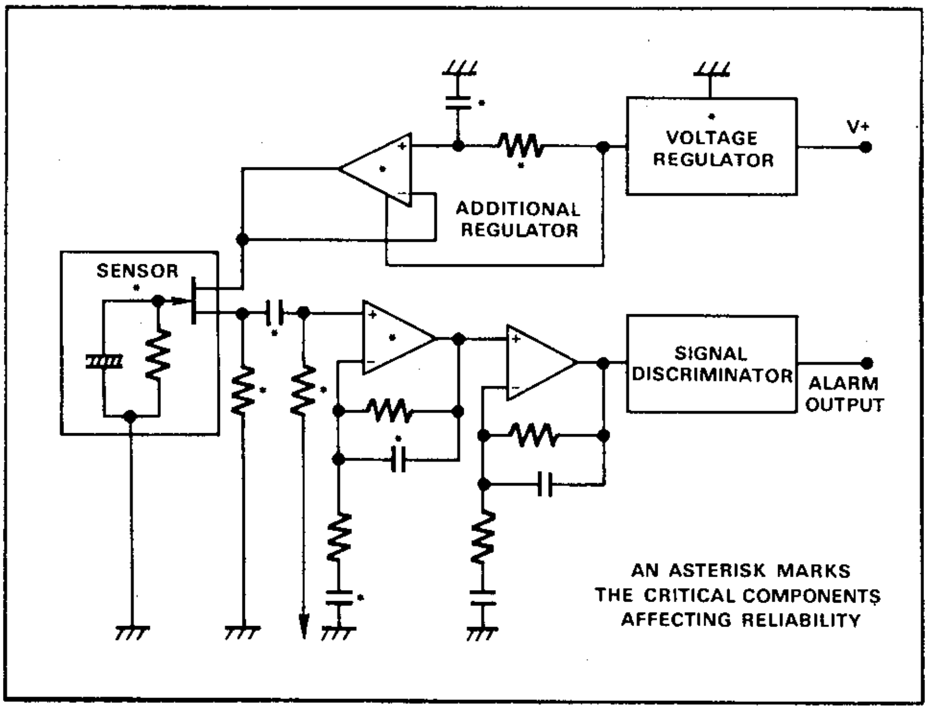

Fig. 10

RELIABILITY

Reliability, or in other words a high detection probability and a low false alarm rate is of primary importance for security systems.

It was generally thought that infrared systems will fail to detect an intruder when the ambient temperature is the same as the skin temperature of the intruder. However, this did not become true as neither the surface of the intruder nor the background have an uniform temperature, and there are always temperature differences that can be detected.

On the other hand, many passive infrared intruder alarm systems suffered from high and unacceptable false alarm rates. The reason and sources of these false alarms are well known today (refer to ELTEC data 104). Careful consideration of these factors allow today to produce intruder alarm devices with excellent false alarm rates of less than one false alarm every 10 years, statistically.

Among the most important factors are:

- Dual element Lithium Tantalate pyroelectric detectors
- Powerful optics
- Careful selection of critical electronic components (Fig. 10)
- Complete electromagnetic protection and shielding
- Sophisticated signal discrimination

Even the natural, extremely low but ever present radioactivity of construction materials used in intruder alarms has been identified as a source of spurious false alarms. Advanced processes can make detectors immune against this.

INTRUDER ALARM SYSTEMS

With the introduction of the high reliability, dual element Lithium Tantalate pyroelectric detector in 1979, **passive infrared** volumetric protection became the most popular system. This because it is the only passive system. No light, ultrasonic or microwaves are emitted with the consequence of complex circuitry, high power consumption and possibly harmful or detectable radiation.

Passive infrared is inherently better than other systems as it detects not only the size, shape and motion of an intruder, but also the characteristic and inevitable body temperature.

Figure 11 shows a typical passive infrared volumetric protection unit for commercial and residential applications. The small and unobtrusive case has an infrared transparent window made of special plastic films, blocking visible light. Below that the opened unit is shown with circuit board and pyroelectric detector on the left and the case bottom with an integrated facetted mirror on the right. (Fig. 11)

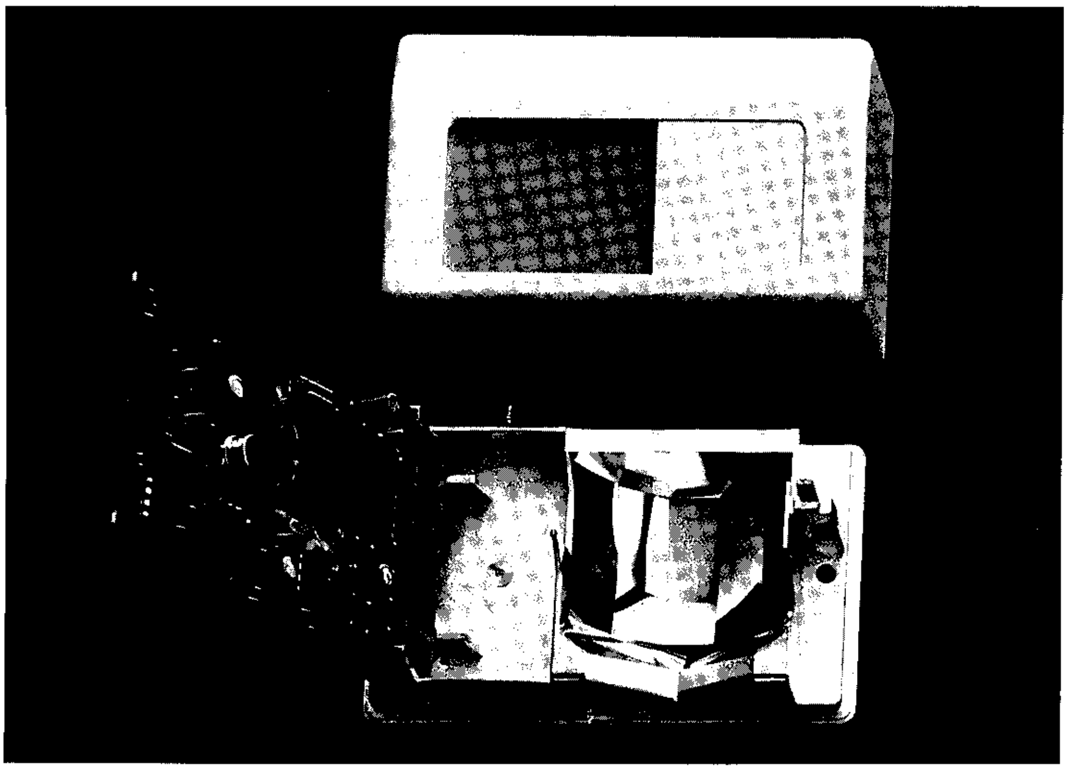

Fig. 11

Fig. 12 shows a single zone unit for outdoor applications. Mounted into a weatherproof housing of only 3 cm diameter, it can hardly be located and shows a significant improvement over large and bulky light barrier or microwave (radar) systems. They are used for perimeter protection of high risk objects like nuclear power plants and military sites as well as for frontier surveillance. The range of the unit extends to 50 meters. It is linked to a buried signal processing unit, and due to its passive operation and special low current detectors used, it can be operated for 10 years from a single lithium battery.

When equipped with a wireless transmitter, it is a simple and effective system for remote surveillance of any object. (Fig. 12)

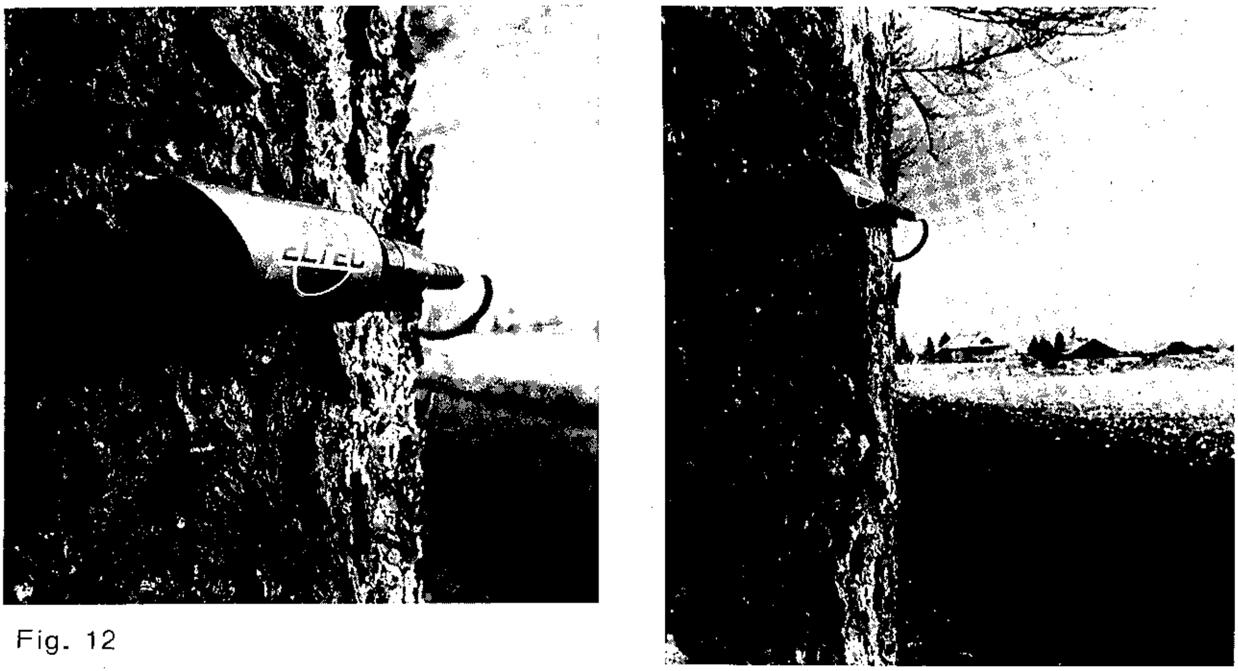

Fig. 12

Another passive infrared unit was originally designed as an industrial control device to count and locate objects in automatic manufacturing processes and to detect overtemperatures of worn tools and bearings (Fig. 13)

But due to its versatility and compact design, it proved to be very practical for many other applications: In industrial areas it can be used as a safety device preventing injury from robots and other dangerous machines. It can also be used for counting people and vehicles passing by even up to the high speeds of trains and airplanes.

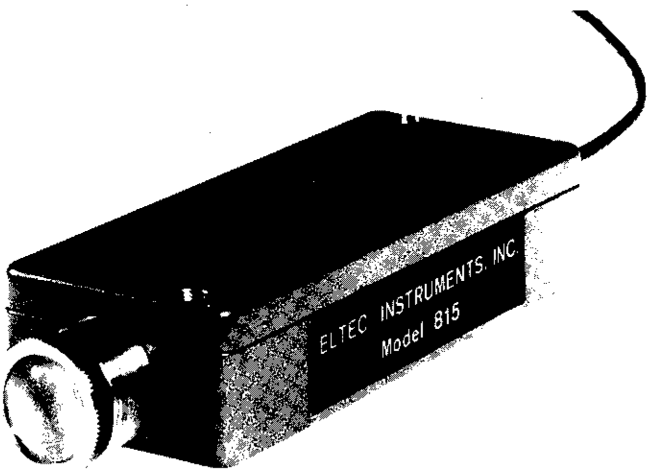

Fig. 13

IMAGING SYSTEMS

An imaging system or "Thermovision" is the direct conversion of the thermal radiation of a scene into a visible image. Such systems are used for example in medicine to make the skin temperature distribution visible or in military and security applications as night vision devices.

Most systems today use either pyroelectric vidicon camera tubes or mechanical scanning with a single, liquid air cooled MCT (Mercury Cadium Telluride) detector and are large in size and very expensive.

Alternative schemes are possible with commercial **Lithium Tantalate** pyroelectric detector arrays. These detectors are available with integrated amplifiers that can directly drive a LED (light emitting diode) display.

Fig. 14 shows the principle of such a system: The radiating object is imaged by the plastic fresnel lens onto the linear pyroelectric detector array. Each detector cell drives an LED mounted on the backside of the array. The LED's give a direct visual image of the infrared radiation impinging on the array. An additional oscillating motion provides a full size image. (Fig. 14)

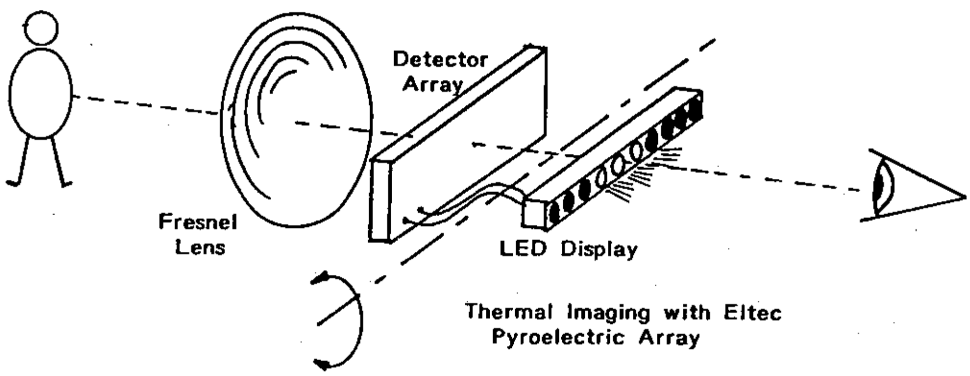

Fig. 14

Although such a system has only about 100 image elements and consequently a very poor image quality and resolution, it can be very helpful to locate intruders and vehicles in the dark and through the fog, and it is relatively inexpensive; battery operated and compact like a small camera.

REFERENCES

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Fig. 7 and Fig. 11 by courtesy of Cerberus Ltd., CH- 8708 Männedorf