INFRA-RED NOVELTIES & OTHER GADGETS

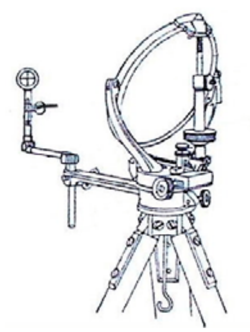
Clive Elliott continues the story about army infra-red systems describing some less well known equipment and deviates into describing some associated gadgets.

SIGNALLING WITH LIGHT

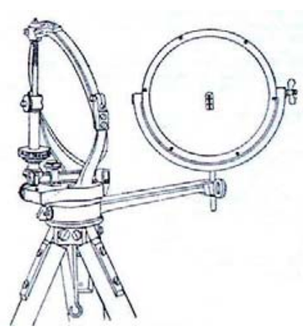
For some thousands of years signalling has been achieved by the reflections of the suns rays or at closer range by the masking of lanterns or beacons. The big step forward was the development of the heliograph.

Heliograph

Communication by heliograph was achieved by reflecting the sun's rays in a precisely controlled way. Under ideal conditions a range of up to 70 miles was claimed for an instrument with a 5-inch reflector. Although mounted on a tripod, further stability could be achieved by hanging a weight from the central hook. Screw-turn adjustment allowed precise alignment both horizontally and vertically. Vertical displacement of the reflector provided the means of 'keying' the light beam on target to create flashes of Morse code characters.

The British Heliograph, 5 inch, Mk V, circa 1922.



Where the sunlight is shining from behind the sender a second 'duplex' mirror is needed to realign the beam.

Lamp Signalling Daylight Short Range

Using sunlight was all very well in the warmer climates of the Empire. But not all warfare would be conducted in such a well-lit environment, or during daylight. The electric light bulb allowed communication at whatever time of day or night. The use of Morse code afforded this digital form of communication great reliability. The illuminating bulb was placed at the centre of focus of a parabolic reflector to direct the beam of light in the appropriate direction, and had the effect of increasing the power of the light by concentrating it in the direction of the recipient. The Lamp Signalling Daylight Short Range offered greater versatility than the heliograph but was more modest in its range:

2 miles	Naked eye	(Daylight)
3-4 miles	Telescope	(Daylight)
6 miles	Naked eye	(Night)
12 miles	Telescope	(Night)

Lamp Signalling Daylight Short Range Projector Mk II with its carrying case which stored the battery. When opened the lid provided a solid base for the Morse key. The box on the left contained spares and filters.

Part of the kit included a filter disc, which could restrict the light output by allowing a group of apertures to be adjusted. The principle being that to reduce the chance of interception, only the minimum amount of light should be used to maintain communication. Yellow, green and red filters could be added. The yellow filter was to make the light source less detectable, the green and red filters were to be used for identification purposes.
For this type of signalling, increasing the reflector size produced a narrower beam, further increasing the range for the equipment. Increasing the power of the bulb could also extend the range. But the limitation of this was increasing the power of bulb the longer was the time for the filament to heat up and cool down. This would give blurring of definition, as the duration of flashes became less precise, loosing the reliability of digital communication. In order to use a high power light it was necessary to use a light source that is permanently on and a series of shutters would define the periods of light. Navies were the principle users of this type of signalling.

PHOTOPHONE

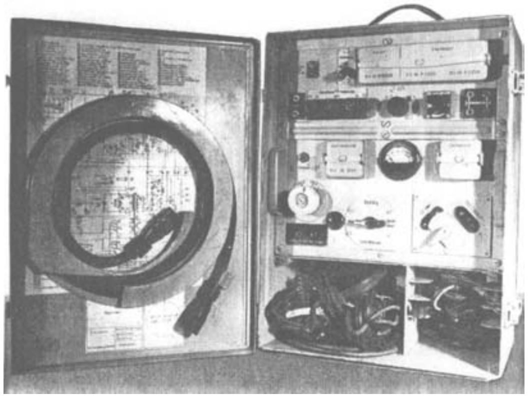
But digital signalling was not the only method of communication using light. As long ago as 1878 Alexander Graham Bell was granted a patent for an analogue way of using light. In this system speech applied to a small mirror caused it to vibrate, a strong beam of light directed onto the mirror would cause the reflected light to varying in sympathy with the speech. At the receiver, a parabolic reflector focussed the light onto a selenium photoelectric cell. The varying light levels were converted into electricity, which could then be interpreted as sound using a battery and an earpiece. This was the first telephone without wires, but the system did not catch on as it was dependant on the whims of the weather, problems of sunlight causing interference, required careful alignment and could be susceptible to jamming or monitoring.

German Infra-red Photophone

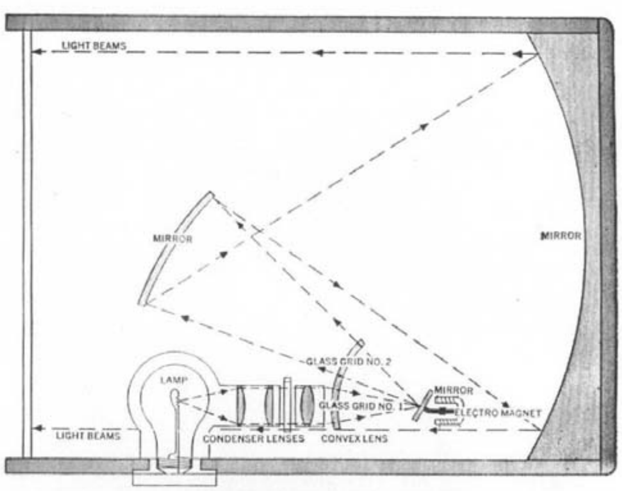
The British, Americans and Germans all used infra-red beams as a means of signalling under the cover of darkness by using digital on/off keying. But it was the Germans who took this a stage further and resurrected the idea of a photophone but using dark red filters to only permit the emission of infra-red energy. This allowed security against the transmitter being spotted in the dark. The receiver also used filters to avoid interference from extraneous visible light and to avoid damage to the sensitive screen in the converter tube. The Allies were fortunate in capturing a German photophone designated *LiSpr 80*, but the results with this were disappointing. But a newer photophone designated *LiSpr250/130* was more impressive with ranges of up to 20 miles. The equipment consisted of an optical unit mounted on a tripod and a separate pack containing the amplifier with storage for the microphone, headphones and connecting cables.

*German photophone **LiSpr 250/130** set up for operation.*

The top of the optical unit contained telescopic sights for initial alignment. The lower part housed the filters and mirrors, which functioned for both transmit and receive.



The amplifier in its case. The cable on the left supplied the optical unit. On the right, is the amplifier, power unit (110/220 AC or 12 DC), and switching to allow connection to an external telephone circuit.

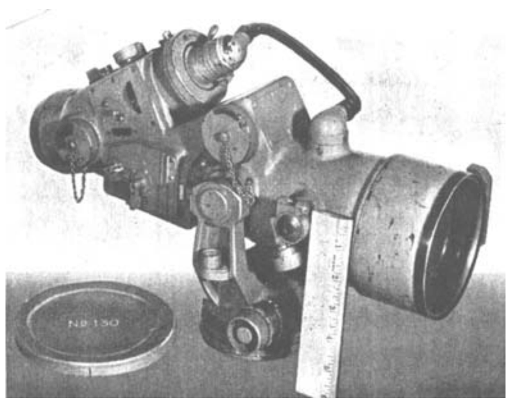


On transmit, the signal from the microphone was amplified and caused an electromagnetic to vibrate a mirror, in a similar way to Bell's photophone. Light from an electric lamp was focussed into a beam of light directed onto this mirror reflecting the light beam in proportion to the speech. Further focussing by parabolic mirrors beamed the light through an infra-red filter to render it invisible to the eye.

At the other end of the link identical equipment focused the beam onto a photocell which was then amplified and received in headphones. Interestingly experiments showed that in good weather even using white or red visible light there was no improvement over just infra-red rays. As long as the beams were accurately aligned increasing distances had no marked effect on signal strength. However under ground haze conditions the infra-red rays penetrated more effectively. Tactically this equipment would lend itself to providing a secure phone link across rivers, harbours, valleys or land terrain where wire or radio links were impractical or insecure.
A limitation to range was the lack of any vernier adjustment of the sighting controls, as increasing range required ever more accurate alignment. A novel feature was an attachment to utilise sunlight as the optical source instead of the electric lamp. An alternative means of communicating was to use a Morse key to interrupt the light beam, or by the use of a hand operated shutter.

Japanese Infra-red Photophone

The Germans were known to have freely passed infra-red technology to their Japanese allies. But it does seem curious that the characteristic Japanese ingenuity of exploiting new ideas did not seem to produce any viable infra-red fighting equipment. But the photophone proved the exception and a Japanese version of the infra-red photophone was produced. Allied tests on the Japanese photophone indicated the system was only useable up to one mile. This limited range was partly due to the smaller size of the optical system over its German counterpart. The concept seems to have been to use the system as an infra-red walkie-talkie for forward observation posts or reconnaissance units. There was a separate transmitter and amplifier powered by a hand generator, which had to be carried by two men. The receiver, with a handheld mirror and detector was a bit more manageable and with the power unit could be carried by one man. The reason for this was that the system could be split up to function with receiver only.



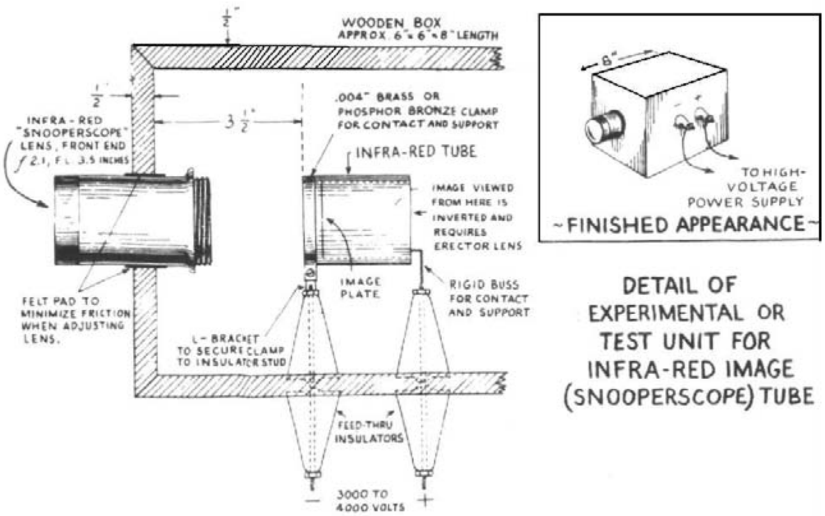
The Japanese photophone transmitter beside a 6 inch ruler.

Should the transmitter be parted from the receiver, there was a built in photocell which could allow two transmitters to communicate. If signals were very weak it was possible to swing another mirror into place although that then prevented the simultaneous transmit and receive facility. Like its German counterpart the light source is modulated by a vibrating mirror on an electromagnet to provide voice communication or could be keyed to provide tone telegraphy.

PLAYING WITH SURPLUS EQUIPMENT

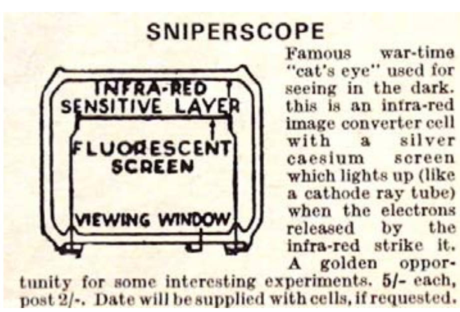
An image converter tube was just a special photocell with the anode being replaced by a fluorescent screen. EMI LTD developed the British Tabby converter tubes in 1940 in less than six months. The speed with which the prototype tubes were produced was a tribute to British wartime effort and the fact in the period 1934-36, a series of articles had been published by German scientists with descriptions of converter tubes! Although development had also been influenced by the description of a converter tube by Holst working for Philips of Eindhoven. So the invention of infra-red vision systems could be claimed by the Dutch, the Germans and the Americans (albeit by a Russian immigrant). However the British would point out that as early as 1926, John Logie Baird had demonstrated a rudimentary infra-red night vision system which he called *Noctovision*.
However the British wartime task had been to develop a simple converter tube that was suitable for mass production. By 1942 large-scale production had been commenced by The Gramophone Co Ltd, and by the end of the war about 100,000 tubes had been manufactured. As so little use of such equipment took place during the war, it meant that a vast stock of tubes and equipment lay unused.

In 1947 it was decided that the Ministry of Supply would release a quantity of these tubes for disposal at auction. It was considered that the tubes could find peacetime applications in industry and for educational purposes. Uses envisaged were the observation of animal behaviour in the dark, extending the use of pyrometers for temperature measurement, and the direct measurement of certain refractive indices with a spectrometer. In the event many tubes ended up for sale to amateur experimenters in magazines such as *Practical Wireless*, but the tubes also ended up for sale in American hobby magazines.



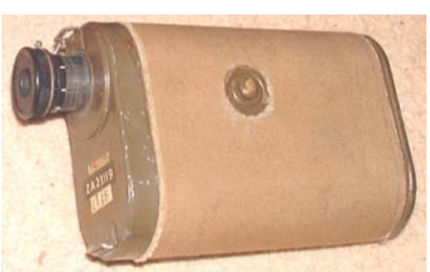
Suggestions for a rather primitive infra-red viewer from an American surplus dealer.

I am sure I wasn't the only schoolboy to have saved up his pocket money to purchase one of these converter tubes with the promise of being able to see in the dark. It was disappointing and perplexing to find that what one had bought was just a glass tube with no lenses, no filters, no power unit and no indication as to how the thing could possibly be of any use at all.



Typical of these adverts was this one from 'Practical Wireless', many of the tubes were marked as officially tested as late as 1955

Later complete Tabby systems appeared on the market, the Tabby Type K monocular seemed a better prospect, as it was a sealed unit incorporating built in batteries.



Tabby Type K monocular

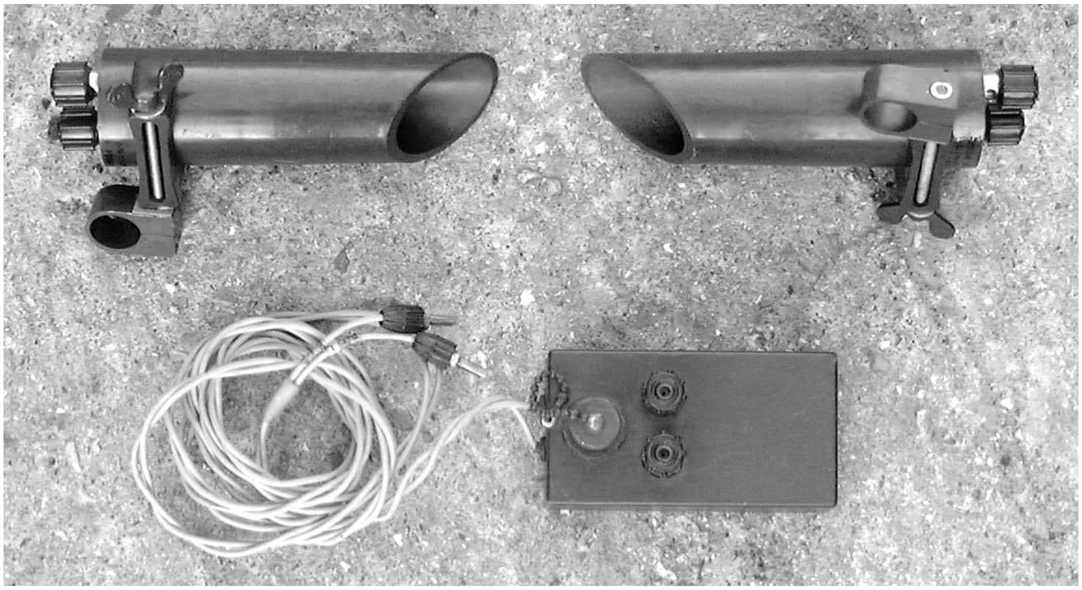
These batteries called Zamboni piles were the development of an electrostatic battery conceived a 100 years before. By using several thousand ¾ inch paper discs coated with tin foil one side and manganese dioxide the other, a voltage of about 3,000 volts was achieved. But by the time the amateur experimenter got hold of this equipment, the batteries had long since expired. Even investigation with a hacksaw and administration of various chemicals to the batteries failed to get even a flicker from the apparatus. So when the complete Tabby Type E installations became available a degree of caution hindered the investment of even larger amounts of pocket money. But it was not until 1984 that I gained sufficient confidence to acquire a Tabby set, but by then such equipment had become quite scarce and required even larger amounts of pocket money. Nowadays, Tabby equipment is extremely rare indeed, although last year I did see a complete Tabby installation kit which went unsold at £250, elsewhere I saw just Type E binoculars in rough condition but complete with tubes which went unsold for £10, so it is difficult to assess a value. Even if a complete power supply can be obtained it would be risky using any such electrical equipment approaching 60 years old, particularly when voltages in the order of 3,000 volts are around. The original power units used a vibrator to produce AC, which was then stepped up with an ignition coil and then rectified with valves into DC. As minimal current is required very small inverters can be built these days powered just by torch batteries. *(For technically minded: I used a 555 astable multivibrator driving to two TIP31C power transistors in push-pull. I fiddled around with odd transformers from the junk box until I found something to give 500 volts output then used Cockcroft-Walton voltage multiplier adding diodes and capacitors until it multiplied up to give 3,000 volts measured on an electrostatic voltmeter. To protect against short circuit of the output I included a 4.7 Meg resistor on the output to the Tabby. Voltages of up to 6.5 kV can be used to give increased brightness and definition but it depends on the tube. Tubes were manufactured as one type, then were selected dependant on the voltage they could withstand, and designated accordingly e.g. CV142 – CV 149, the most commonly used of the tubes was CV144.)*

INFRA-RED INTRUDER ALARMS

We are all familiar with modern passive infra-red (PIR) intruder alarms that are quite readily available. These sensors work at the far end of the infra-red spectrum detecting body heat and then detecting when the level changes with movement. In general these detectors have a wide arc of coverage and a relatively short range. They can be prone to false responses with reflections from moving leaves, animals etc. So not a system that would lend itself well to securing a battlefield position. A far more effective way of defining a secure area is to use a series of infra-red beams to encompass the protected area. An example of such as a system is called IRIS.

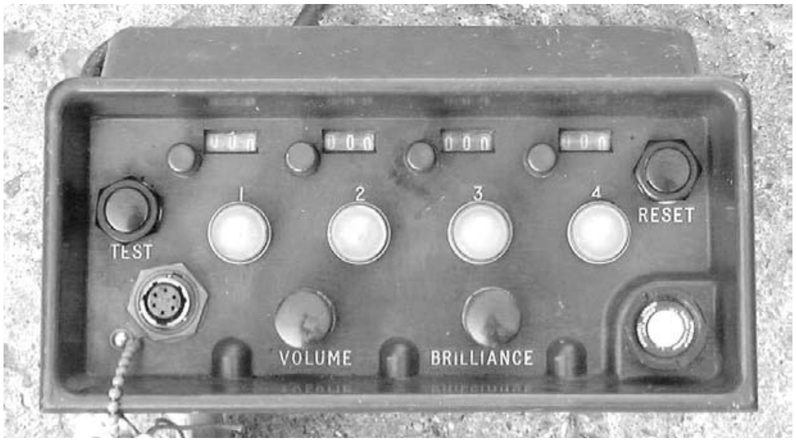
Alarm Set, Anti-Intrusion, Restricted Area (IRIS)

IRIS was developed by GEC-AEI (ELECTRONICS) LTD for use with the British Army. Introduced in the late 1960s these kits are often seen on sale at MV shows. They comprised a set of four transmitters (filtered light bulb & reflector) and four matching sensors (filtered photocell & reflector). Because of the narrow beamwidth careful alignment was required and they needed to be well secured into the ground. The transmitters, which were powered by their own dry batteries, were usually secured at the more remote point. The sensors must have wires that lead back to the control monitor, not only to send the alarm but also to receive power to work a three-stage transistor amplifier. The alarm was triggered when the infra-red beam was broken by attacking troops. But other things such as, leaves, animals, birds, bats, moths, etc could interrupt the beam. To get around this problem the infra-red beam was chopped i.e. interrupted in a special sequence and different objects interrupting the beam produce a characteristic response in the receiver, which can be allowed for. (Technical: pulsed at 1.5 kHz, mark to space ratio 1:7). Not entirely foolproof but the chopping did rid the system of what would be a large number of false alarms, and helped prolong battery life. As the beam of infra-red was only 3 degrees wide, it required very careful alignment. It was recommended that alignment was carried out by two men, and normally should be successful by using the rudimentary sights on the top of each unit. But for alignment at night or where the units were well camouflaged from each other, an alignment aid was provided. By plugging into the sensor, the alignment aid gave an audio note to headphones with a volume proportional to the strength of the beam from the transmitter unit. This avoided any reference to the main control unit, which may be up to half a mile away. Given the narrowness of the beam it was important that transmitters and sensors were kept on heading, so the kit provided ground mounting stakes and if more appropriate corkscrew type tree stakes could be used.



On the left is the IRIS transmitter, which externally appears very similar to the sensor on the right. To try to avoid confusion each was embossed with 'T' or 'S' in unnecessarily small type. The alignment aid is below, with a pair of wires, which were plugged into the sensor. Once aligned the unit was unplugged, and the sensor was connected via D 10 wire to the main control unit.

The control unit used an external 12-volt dry battery; the four incoming double cables were attached to the rear of the unit. The control panel monitored each of the four channels simultaneously. When a beam was broken the operator was alerted by a warning signal in his headphones, a light indicated which channel had been triggered, and a counter for each channel recorded the number of alarms. A reset button, lamp dimmer, volume control and test button were also provided.



The monitor unit, at the top can be seen the hinged cover to protect the terminals that connect to the sensors

The system is fail-safe, so in case of sabotage or failure of any part of the system, the alarm will be triggered. The system will operate by day or night, provided there is direct line of sight between the transmitter and sensor. Under good conditions the range between the transmitters and sensors can be up to 220 yards. In fog, snow, rain etc where visibility is less than 55 yards in daylight, the range is restricted to the equivalent daytime range of visibility. Although the sensors can be up to half a mile away from the control unit, if the loop resistance of the connecting cable is less than 600 ohms the range could be as far as 3 miles.

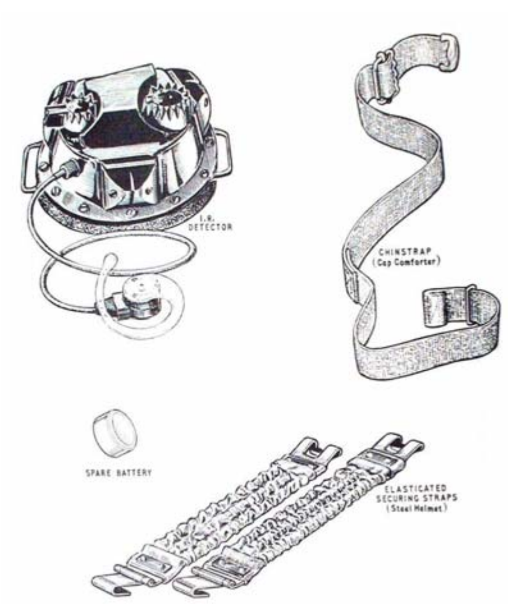
INFRA-RED DETECTING ALARMS

Troops or vehicles may not necessarily be equipped with infra-viewers either because there is not enough equipment to go around, or there may be other tasks to perform which preclude continual starring into a viewer. Yet it would be highly desirable to know whether there is an infra-red beam being directed at you from enemy sources. That enemy beam may mean one is under general surveillance, or a security anti-intruder beam is operative, or even that one is being observed by a weapon sight. There were two systems introduced by the British Army during the 1960s.

The Detecting Set Infra-red Head Mounted

Operational use of detector against infra-red beam.

Manufactured by Plessey this detector, with its slightly comical appearance, could be mounted on a helmet, or worn over a beret or cap comforter. It consisted of three infra-red detectors mounted to each give 120-degree horizontal coverage; vertical coverage was 50 degrees above horizontal and 40 degrees below. The detector housed a 1.35 volt Mallory battery and amplifier produced a low frequency buzz in an earpiece when infra-red energy was detected. The earpiece incorporated a retaining clip that only permitted it to be worn in the right ear, however the lead is actually long enough to allow the left ear to be used. It is a simple matter to remove three screws to allow the ear-retaining clip to be reversed, and as the fixture has countersunk holes on both sides it suggests this was a legitimate modification. The detector could be attached to a GS or parachutists helmet by elasticised straps. Alternatively by use of a chinstrap, the detector could be worn on a beret or cap comforter. It was important that some head covering was worn to prevent the detector from sliding on the hair.

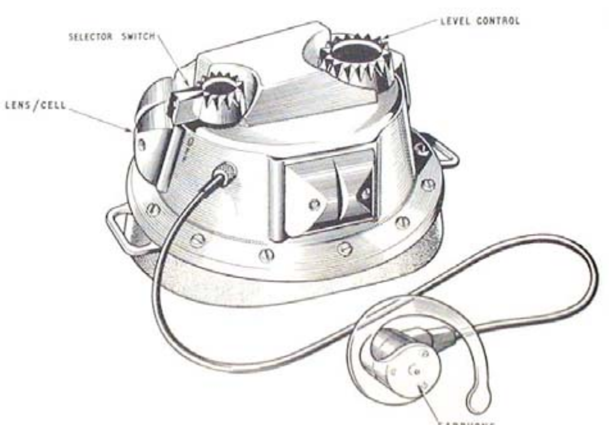


Items of equipment

Attachment of infra-red detector to helmet

Infra-red detector in use without helmet

There were two controls on the detector, a sensitivity control and a three-position switch. The central position of the switch is off, with the control pointing to the rear all three sensors are active, and when forwards only the forward facing sensor is active. With this facility it would seem feasible to turn the detectors off when an alarm was sounded to gain some idea of the direction of the enemy beam. But the official purpose was to blank off interference from a sector which might respond to friendly infra-red beams or lighting. The way to judge the direction of the beam was to hold a hand in front of each sensor until the alarm stopped. The sensitivity control was to allow for variations of ambient light e.g. moonlight.



Controls on the infra-red detector

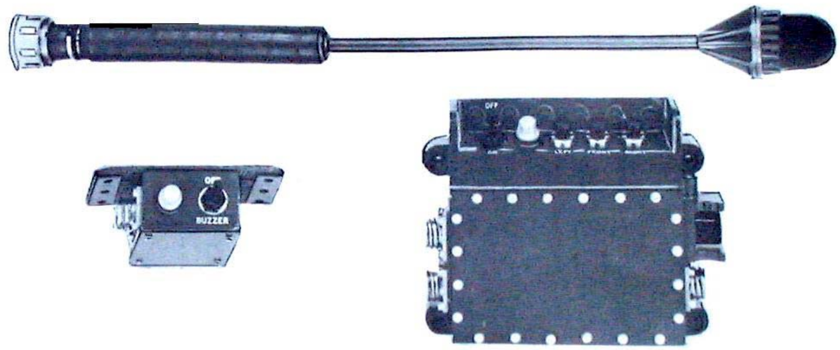
The range of detection would depend on the power of the infra-red source and the degree to which the sensitivity control had been turned down to allow for moonlight. Two examples quoted for bright moonlight conditions were:

(a) Detection of a 2 kW Zenon arc searchlight at more than 5 km distance.

(b) Detection of a Weapon Sight source up to a distance of 400 to 500 metres. Under ideal conditions the maximum range of an IR Weapon Sight is about 275 metres against moving personnel, or 350 metres against moving vehicles. Thus the wearer of the detector would receive a warning of the existence of a beam from a Weapon Sight prior to coming within its range. However there would be no protection for the wearer intruding where narrow beams are used in a system such as IRIS. Because as soon as the beam was detected by the intruder, the alarm would be raised by the interruption of the security beam.

Infra-red Vehicle-mounted Detector

This was a more elaborate detector specifically designed for use in the Chieftain tank. The detector was mounted on a 2 foot long slightly flexible stalk fitted on the top off the tank, which contained three sensors each giving 120 degree coverage. A separate control unit amplified signals from the detector to trigger an alarm on a small unit with a buzzer and a warning light to alert the commander of the presence of an infra-red beam.



Above is the stalk, with the detectors mounted within the dome at the right, the thickened section is of rubber which allowed some flexibility. Below, the larger unit is the main control unit, and the smaller unit housed the buzzer and warning light.

The detector headed was positioned so that an arc of coverage was provided from a sensor to cover the area in front of the tank and the other two sensors covered the remaining arcs on the left and right sides. The sensors although embedded in clear plastic were further protected inside a black plastic dome. The dome was made of ¼ inch 'Tyril' which was a material that was opaque to visible light yet reduced the sensitivity to infra-red by only 5%.

The 'Tyril' dome removed showing the sensor head. Note the arrow allowing alignment with the front of the tank.

The control unit incorporated push buttons, which could turn off two sensors at a time. So contrary to the use of the head mounted version the switching of sensors was intended to give an idea of the direction of the offending beam. The push buttons proved tiresome to use and were unreliable; these were later replaced by toggle switches. The range was at least 500 yards when illuminated directly by a 15-watt infra-red searchlight. Although originally intended for the Chieftain tank there is no reason why the equipment could not be installed on any other vehicle. In fact some Ferrets were fitted with this equipment in the Gulf war. This was a prudent step as a number of captured Iraqi AFVs were found to still be using active night vision systems i.e. they had infra-red searchlights.

SEISMIC SENSING

Although seismic sensing is not an infra-red system it is described here as it was often used in tandem with IRIS. Circumstances of the location may not permit a total security by IRIS; this might be the foliage precluding establishment of a satisfactory infra-red beam or heavy rain. Instead a seismic type of alarm system could be employed or indeed where additional security was required both systems could be used.

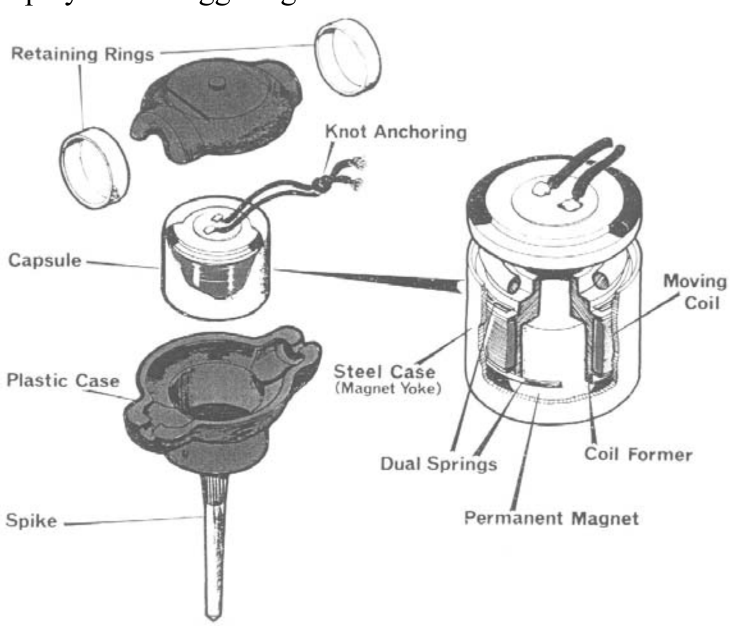
Detector, Seismic Intrusion (Texas X150A)

The Texas X150A was a commercially available seismic detector which consisted of special microphones (seismometers) placed into the ground connected by wires to a common control unit. An operator using headphones monitored tiny vibrations in the ground. Typical sensitivity was a radius around each sensor of 30 metres for footsteps, or 100 metres for vehicles. In use with the British Army in 1967, it did not enjoy widespread deployment, principally because the whole set-up was not very rugged.

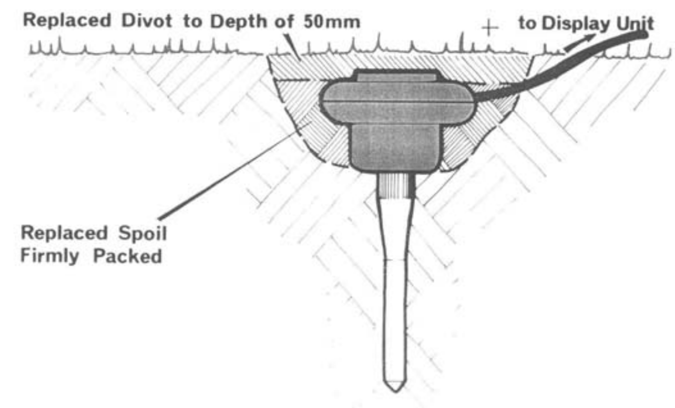
Texas X150A control unit measuring 7 x 4 x 9 inches shown with one seismometer.

TOBIAS

A more advanced seismic alarm system was Alarm Set, Anti-intrusion, Restricted Area (Elliott C769), more commonly know as TOBIAS. The Army derived this from Territorial Observation By Intrusion Alarm System, although the manufacturer in defence catalogues stated that it was derived from Terrestrial Oscillation Battlefield Intruder Alarm System. TOBIAS was introduced into British Army service in 1969 and was widely used, and many of the earlier versions appear on the surplus market. Ground microphones, referred to as geophones, were pushed into the soil and wires were fed to a control unit where the sound was amplified. An acoustic alarm was heard by the operator who could switch between microphone circuits and see a meter display of the triggering stimulus.



Geophone construction



Positioning the geophone

Detection ranges varied according to the ground conditions but would normally be no less than 30 metres radius from each geophone. The range could be reduced by other vibrations such as heavy rain, hail storms, traffic, movement of friendly personnel etc. The system could also be used to detect movements in buildings, tunnels and even riverbanks provided there was not excessive noise from water flow. There were three marks of control unit; the Mk 1 was made from fibreglass and the Mk 2 and Mk 3 from alloy. There were some minor changes between the different versions, but the most extraordinary feature was that so little effort went into protecting the three flimsy wires from the battery container in the lid to the terminals on main control panel. The lid instead of being hinged was held by toggle clamps. The lid was heavy with the weight of the batteries, so when opened it tended to fall. It was so easy for the wires to become detached and easy to make an error in connecting them up again. A very poor bit of engineering for something to be used in the battlefield, in sharp contrast to the rugged construction that was used in radio equipment.

TOBIAS Mk1. Note the flimsy aluminium stays carried in the lid housing the battery box beneath. The delicate cable feed was attached to the main unit via terminals on the right hand side.

The batteries were 8 x 1.5 volt U2 cells, arranged to give 9 volts and 3 volts. Unfortunately the different current drains meant one set of batteries would last 200 hours, but the other set only 60 hours, which did not bode well for reliability. However there was the facility to switch one on the meters to measure battery voltage. A trigger from any of the four channels would give an acoustic alarm in the headphones of the operator. Each channel had its own meter to indicate which circuit had been triggered, and had a facility for testing the continuity of each circuit.

INFRA-RED VIEWERS

British infra-red viewing

During the war with an infra-red viewer and spotlight were fitted a Sten gun. But this proved not to be a practical weapon.

What isn't shown is the bulky power supply that was needed.

After the war many armies were keen to exploit the facility of infra-red night vision. This equipment still needed a source of infra-red to illuminate the scene; such equipment ranged from small hand held units to massive searchlights. An infra-red weapon sight was originally developed for fitting to a rifle, but also found some success fitted to a GPMG and the Carl Gustav anti-tank weapon. Powered by a 6-volt battery, a single transistor oscillator generated AC, which was multiplied and rectified to provide 12,000 volts DC. This HT was at very low current to activate the image converter housed in a monocular fitted to the weapon. An infra-red spotlight mounted above the viewer illuminated the target.

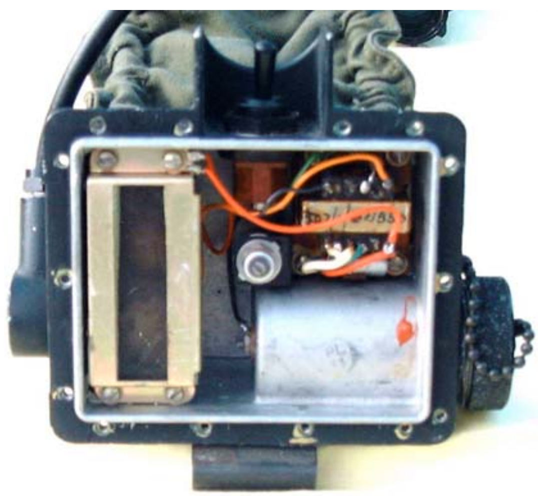
The rather cumbersome infra-red weapon sight on a rifle

But for night driving the infra-red source was provided by the vehicle. This was in the form of infra-red filters, which were attached to the vehicles normal headlights. They were fixed by slots that located into protruding bolts fitted to the standard FV pattern headlight. But in the case of many AFVs, dedicated spotlights were used for infra-red driving. The most widely used viewer was known as the Common-user Binoculars or more correctly Receiving Set, Infra-red, Binocular, No 1 Mk 1, Cased. The unit was self-contained and was fitted to the standard steel helmet. The binoculars were attached at the front of the helmet, and held in place by a wide elasticised canvas band supporting cables to the power unit clipped to the rear of the helmet. Mounting the power unit here provided a counter balance and avoided problems of dangling cables.

Receiving Set, Infra-red, Binocular, No 1 Mk 1, Cased

Binoculars partially dismantled showing the image converter removed which measures 2.25 inches long and 1.4 inches wide

A 1.5 volt battery via a single transistor inverter provided the necessary 12,000 volts for the converter tubes. This was considerably more than the wartime Tabby tubes, which were only able to withstand 3,000 volts. We were now using voltages that gave a much greater sensitivity as the wartime German equipment had demonstrated.



The very compact power unit. To the lower right is the battery container, above that the single transistor and transformer, and to the left is the voltage multiplier unit. In the centre is a potentiometer to provide adjustment of the output voltage.

A range of 300 metres was claimed for the Common-user Binoculars but this was dependent on the potency of the infra-red source used. The trouble with all of these systems was that they were active systems, i.e. they required a source of infra-red. But active systems can also be detected by the enemy. Next time I will describe some passive systems which will include image intensifiers and thermal imagers.