THOMAS
JACKS

A BASIC GUIDE TO NIGHT VISION

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CONTENTS

1 NIGHT VISION - PAST, PRESENT AND FUTURE

People have many requirements to see at night and powerful illumination systems have been around since the first lighthouse went into service at Eddystone Rock in 1698. However, these systems were simply methods of illumination with the obvious, and sometimes very dangerous drawback, that everyone could see the source of the light. For this reason it became vital that a solution be found for military use - a decisive advantage was to be achieved by gaining the ability to see at night without being seen.

In 1887, Heinrich Hertz first discovered photoemission, on which night vision technology is based. In 1905, no lesser person than Albert Einstein theoretically explained the principle - the release of electrons from a solid material due to energy put in to it from radiation and light.

The breakthrough came about in 1936 when the first Active Infrared system was developed using a silver photocathode. These systems were very bulky and primitive by todays standards, but at the time they represented a major military advantage. Active Infrared systems continued in use until the late 1970's in some countries, but NATO forces were phasing them out by the late 1960's. The main drawback of Active Infrared systems was that to operate they required powerful infrared lamps, which meant the range was restricted by the performance of the lamp. In addition, although infrared is not visible to the naked eye (other than a very dull red glow if you are close to the lamp), a major problem would arise during covert operations where both sides were using Active Infrared systems, in that each side could see the light emitted by the others infrared lamp. Therefore, you are back to square one. With the source of the light easily identifiable the system was rendered virtually useless, and probably lethal, as you would only have to shoot at the lamp to take out the person using it. It was at this point that new technology was urgently required and modern Image Intensifiers were developed.

The advantage of these systems was that infrared lamps were no longer vital, and for this reason they are referred to as Passive Night Vision devices. However, all Image Intensifiers need some light to work because by their very nature they amplify the available light to give a visible image. If an area is pitch black with no ambient light at all, no Image Intensifier will be able to function. For this reason infrared illuminators still play an important role and will always enhance Image Intensifier performance, but at the expense of losing the covert capability.

Night vision ability can also be realised through the use of Thermal Imagers, which perform a similar function to Image Intensifiers, but with the big advantage of being able to operate in zero light conditions as well as fog, smoke, snow, etc., which is not possible with night vision devices. The latest, most sophisticated thermal imaging equipment will locate people or vehicles in trees, buildings and through a variety of media. Although there are methods to defeat them, doing so can be difficult and expensive. Thermal Imagers obviously detect heat and not light energy and the images they produce are generally less well defined than those of an Image Intensifier. As range increases the subject simply becomes a hot 'spot'.

Although Thermal Imagers have been around for some time, the early devices required a cooling system, which was usually compressed gas, and their size and weight restricted them to static observation and surveillance work only. With the development of uncooled solid state models, they have become portable and a potential rival to the Image Intensifier. However, a major drawback to Thermal Imaging is cost, with basic systems starting at around £10,000 and the military/police equipment at many times this.

There is one other area of development concerning night vision ability and this centres around the use of computers. Increasingly, developments in CCD technology are producing low light images of impressive quality. It is already possible to integrate and 'build-up' a visible picture but the problem here is that you do not get a real time image, giving a blurred and distorted picture if your equipment or subject is moving. The technology also already exists where the system gathers whatever information it can on the subject being viewed and in low light conditions where it is information limited, will 'fill in the holes' to produce a full, if not completely accurate, image.

As for the future, it is certain that technological developments will allow the improvement of all the systems already existing, but it is also likely that systems will be combined and integrated into smaller, more efficient devices where two or more technologies can be alternated at the touch of a button.

2 LIGHT AND DARK

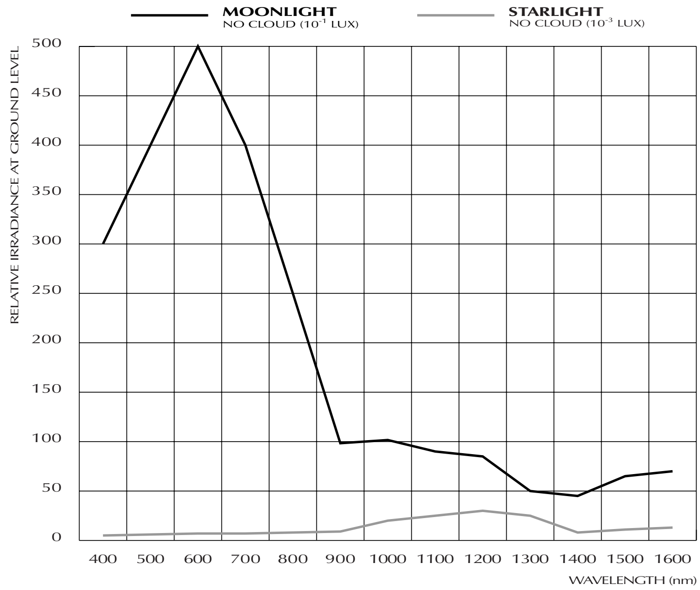
We measure the level of light falling on a scene in units called lux. A sunny day can be 10,000 lux, and a bright office about 500 lux. At sunset under a clear sky and in an open area, the level will have fallen to 100 lux. At night, artificial lighting maintains the centres of towns at roughly 10 lux. At this level colours start to lose their brilliance. The brightest moonlight produces about 0.1 lux and our eyes can then see little colour at all. Starlight levels are less than 0.001 lux. It then becomes difficult to move around with any confidence because we are only vaguely aware of the largest shapes and objects that move. Light levels below this are now uncommon in the developed world, except in the remotest rural areas.

NATURAL LIGHTING	LUMENS/METRE^2 (LUX)
DIRECT SUNLIGHT	1.0 t0 1.3 x 10^6 (100,000)
FULL DAYLIGHT	1.0 to 2.0 x 10^4 (10,000)
OVERCAST DAY	10^3 (1,000)
VERY DARK DAY	10^2 (100)
TWILIGHT	10
DEEP TWILIGHT	1
FULL MOON	10^{-1} (0.1)
QUARTER MOON	10^{-2} (0.01)
STARLIGHT	10^{-3} (0.001)
OVERCAST STARLIGHT	10^{-4} (0.0001)

APPROXIMATE LEVELS OF NATURAL LIGHTING AT GROUND LEVEL

Light consists of small particles of energy called photons. Lower light levels mean fewer photons. If a picture contains insufficient photons it will lack information and be incomplete. We do not usually notice this effect because our eyes and brain have evolved to overcome this. There is an increase in the period over which photons are collected by the eye before the picture information is passed to the brain. Rather like setting a slower shutter speed on a camera, the eye slows down to about 1/5th of a second. In addition, the pupil opens wider (fully dilated at 7mm) to let in more light, and a more sensitive set of detectors come into use at the rear of the eye. These can only see in black and white, which is why we lose our sense of colour in the dark. This whole process is called ‘dark-adaptation’ and takes tens of minutes to acquire fully (generally about 40 minutes), but is lost again by the briefest exposure to any bright light source - even a match.

The widespread use of artificial lighting can prevent our eyes from becoming dark-adapted. Our workplaces are lit to regulated levels, we walk along well-lit streets and drive behind powerful headlights. It is unlikely that the inhabitants of towns and cities ever become truly dark-adapted.



REPRESENTATIVE SPECTRAL DISTRIBUTION OF MOONLIGHT/STARLIGHT

As darkness falls, there comes a point when we can no longer see properly and our eyes need help. In developed areas, where there is usually some artificial illumination, this can often be achieved by using good quality low light binoculars, such as 7x50 or 8x56, which simply magnify objects so they become more clearly visible. Beyond this, the use of a night scope becomes necessary.

When an Image Intensifier is used in really dark conditions the quality of the picture on the phosphor screen drops dramatically. Its overall brightness level falls and individual scintillations, tiny flashes of light, become more clearly visible. Such a picture is said to have become ‘noisy’ and we describe this situation as being ‘information-limited’. The only way to improve any image that shows signs of information-limiting is to increase the number of photons used to create it.

A few of the basic problems of seeing at very low light levels are so fundamental to the physical state of darkness that they can only ever be overcome by the use of active illumination, be it visible or covert. All generations of Image Intensifiers need light to work - they cannot provide a useful image in complete darkness. They are, however, sensitive to infrared (IR) light. In starlight, some 70% of light is in the infrared spectrum. The introduction of semi-covert/covert illumination overcomes this problem and users should consider having some sort of IR illuminator available to assist the Intensifier when climatic or lighting conditions restrict its performance.

Lamps with infrared (IR) filters offer good range and are eye safe, but they are bulky, can consume a lot of power, get hot and can exhibit a very visible red glow. Infrared illuminators using LED’s are eyesafe with many devices having a short-range one built-in. With many of these the useful range is restricted to ≤50 metres, but more powerful add-on variants are available. Most Gen 1/ Super Gen 1+ and Gen 2 systems are most sensitive in the semi-covert spectrum of IR (800-850nm) and IR illuminators covering this may exhibit a red glow from the LED. Only Gen 3 and digital systems are sensitive enough to be used with truly covert (900nm+) IR illuminators. Laser illuminators are the best compromise of size and power, but most are not eye safe - they can burn the retina at the back of the eye even at substantial range. There is, therefore, a major liability in using such a product. The only high power Class 1 certified eyesafe laser currently known to be available is from LaserLuchs. They are compact, give very good range capability and have a very ‘clean’ - no blemishes - circular output.

The use of IR illuminators is the most cost effective way of getting big increases in Intensifier performance. The downside would be if someone else was also using a night scope in the same area - they would potentially see your IR illuminator very clearly.

3 THE IMAGE INTENSIFIER

Night Vision scopes are electro-optical devices that intensify (amplify) available light. The main component of such a device is the Image Intensifier - basically a vacuum tube. At the input end, the objective lens collects the particles of light (photons) arriving from the subject and focuses them on the image intensifier tube. Inside the image intensifier tube a photocathode absorbs these photons and converts them into electrons which are amplified and projected on to a green phosphor screen at the rear. When this highly intensified electron image strikes the phosphor screen, it causes the screen to emit light that you can see. Since the phosphor screen emits this light in exactly the same pattern and degrees of intensity as the light that is collected by the objective lens, the bright night-time image you see in the eyepiece corresponds closely to the outside scene you are viewing. The phosphor screen is coloured green because the human eye can differentiate more shades of green than any other phosphor colour.

The number of times the screen image is brighter than the one arriving at the photocathode is called the gain of the Intensifier. However, gain is a function of two factors, the ability of the photocathode to convert the weaker photons into electrons, and the amount of amplification which accelerates these electrons onto the screen. If the type of photocathode is fixed, more gain means more screen brightness, not the ability to see better in the dark. There are two ways to measure gain - tube gain and system gain. Tube gain is usually seen in values of tens of thousands and is more a laboratory figure that is not necessarily indicative of a devices performance. If tube gain is too high, the tube will be “noisier” and the signal-to-noise ratio may go down. System gain is based on the total system ie. tube, optics, power supply etc. System gain is usually seen in the low hundreds for Gen 1, mid-hundreds for Gen 1+ and 1000-3000 for Gen 2/2+/SuperGen/HyperGen and Gen 3. System gain is the figure that potential night vision purchasers should compare.

4 THE GENERATION GAME

Image Intensifiers exist in several shapes and sizes and four main generations. Gen 0 and Gen 1 systems use electrostatic inversion and electron acceleration to produce gain. Both are characterised by geometric distortion, but Gen 0 requires active infrared illumination, whereas Gen 1 has higher photosensitivity and was the first truly passive image intensifier. Gen 1/Super Gen 1+ offers the optimum in performance/cost-effectiveness for the non-professional user. One of the unique characteristics is that it can potentially stay 'on' for some time after it is physically switched off due to it holding a residual charge. Gen 2 and Gen 3 systems do not suffer this 'afterglow' - the image disappears as soon as they are switched off. They are generally smaller in size and weight and use noticeably less current. They both use a microchannel plate (MCP) to improve gain and image resolution, but on Gen 3 the tube is also coated with an ion barrier film to increase tube life. However, they are very similar internally with the main difference being their photocathodes. Whereas Gen 1 and Gen 2 photocathodes may be the same (Tri-Alkali), Gen 3 technology is based on a completely different substance, Gallium Arsenide, that is up to three times more light sensitive.

Be wary of systems claiming to use US Gen 2+ image intensifier tubes. The US has manufactured only Gen 3 tubes for most of the last 10 years. The likely source for any US Gen 2+ tube is therefore military warehouse clearance stock. Whilst you may be lucky to get a tube that has been sitting as a spare, it is still many years old and unlikely to offer the performance of current production. Worst case scenario is that you get a well-used, lifetime limited tube with much reduced sensitivity due to usage and age.

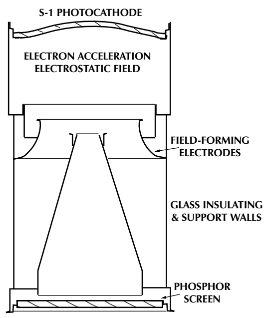
Although Gen 3 intensifiers are the most sensitive, they are not necessarily the best for all applications. They are more highly sensitive to the invisible, near infrared part of the spectrum. In many urban and suburban areas lit by street lights, there are insignificant amounts of near infrared. Gen 3 performance then appears to be no different to that of the earlier generations. In fact, Gen 3 systems tend to 'white-out' when exposed to high light levels losing a lot of image detail and contrast. They are really only seen at their best in the very darkest rural locations.

Latest development is auto-gating image intensifier tubes. These are designed to give optimum performance and minimal halo when scanning from very dark to light areas or vice versa. This makes them the most effective solution for urban operations and offers the best protection where there is likely to be bright light sources such as street lights, car headlights etc.

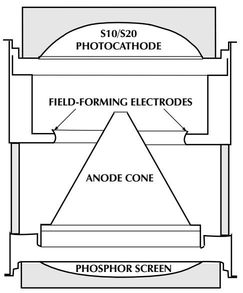
It is more true of night vision than almost any other product, you really do get what you pay for. There is a noticeable performance advantage as you work up the intensifier tube scale. However, as with many products, the percentage of performance gain reduces compared to the noticeably increased outlay in cost for the highest capability units.

Generation 0 - Typically uses an S-1 photocathode with peak response in the blue-green region (with a photosensitivity of 60 uA/lm) using electrostatic inversion and electron acceleration to achieve gain. Gen 0 tubes are characterised by the presence of geometric distortion and the necessity for active infrared illumination.

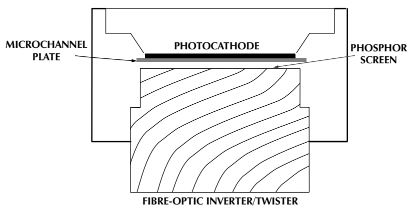
Generation 1 - Typically uses an S-10 or S-20 photocathode (with photosensitivity of 120-200 uA/lm), electrostatic inversion, and electron acceleration to achieve gain. Because of higher photosensitivity, Gen 1 was the first truly passive image intensifier. Characteristics of Gen 1 include high voltage power supplies, geometric distortion toward the periphery, reasonable performance in low light and 'blooming'. The tube can potentially hold a charge for some time even if no power is being supplied, the image just gradually fading. Tube gain varies between 100-500x - beware of claims for much higher values. Resolution in the centre varies between 25-30 lp/mm. Gen 1 tubes generally have a high power requirement which can mean that they emit a high pitched tone when driven hard - especially true of twin tube designs (binoculars/goggles). Due to the manufacturing process it is usual to find cosmetic blemishes (spots/patches) in the tube - these are considered normal and are not a defect. Most budget Gen 1 night vision tubes are manufactured in Russia/Belarus - they account for approximately 95% of the world market. Typical MTTF: 1000 hrs.



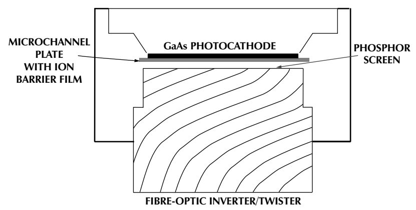
GEN 0



GEN 1



GEN 2



GEN 3

CF Super/Super Generation 1+ - True CF Super/Super Gen 1+ tubes are only available from one source - Pulsar/Yukon Advanced Optics. They feature the addition of a fibre optic plate (not an MCP) on the front of the tube. There is less geometric distortion which gives much better edge-to-edge definition than standard Gen 1 tubes. Resolution in the centre can be as good as 42 lp/mm (a 30% increase over the best Gen 1) and there is much reduced geometric distortion around the periphery with a resolution here of about 32lp/mm. These are the first systems that allow the possibility of reasonable still photography and video imagery through the scope. Beware of some companies claiming to offer 'Gen 1+' models - many are really only Gen 1, not Super Gen 1+. Typical MTTF: 1000 hrs.

Generation 2 - Usually an S-25 (extended red) photocathode (with photosensitivity of 240-350 uA/lm) with a microchannel plate (MCP) to achieve gain. Normally uses fibre-optic inversion. Gen 2 tubes provide good performance in low light levels and exhibit very low distortion making them reasonable for use with video or still cameras. They are equipped with automatic gain control, flash protection and feature edge-to-edge definition. Resolution in the centre varies between 28-32 lp/mm. They are more tolerant of urban lighting than Gen 3 systems. Typical SNR: 11. Typical MTTF: 2000 hrs.

Generation 2+ - Based on Gen 2 tube technology, but has enhanced photocathode sensitivity (typical photosensitivity of 350-450+ uA/lm). Resolution in the centre varies between 32-40 lp/mm. Typical SNR: 13. Typical MTTF: 2000 hrs.

SuperGen - Based on Gen 2 tube technology, but with further enhanced photocathode sensitivity (photosensitivity of 500-600 uA/lm). Resolution in the centre varies between 45-54 lp/mm. Typical SNR: 18-21. Typical MTTF: 10000 hrs.

HyperGen - The highest development in Gen 2 tube technology, with further enhanced photocathode sensitivity (photosensitivity of 600-800+ uA/lm). Now available with the option of auto-gating, improving capability in scenarios where lighting changes from dark to bright very rapidly. Resolution in the centre varies between 55-72 lp/mm. Typical SNR: 20-28. Typical MTTF: 15000 hrs.

Generation 3 - Uses gallium-arsenide for the photocathode and a microchannel plate for gain. Can produce more than 800 uA/lm in the 450 to 950 nanometer region of the spectrum. Gen 3 provides very good to excellent low-light-level performance and long tube life. Gen 3 tubes show virtually no distortion. Resolution in the centre varies between 45-64 lp/mm. All countries producing Gen 3 image intensifier tubes strictly control the availability and export of these systems - in many, they are limited to strictly military/government agency use. Typical SNR: 18-28. Typical MTTF: 10-15000 hrs.

Digital NV - Utilises a CCD sensitive in the IR spectrum and an LCD screen. Primarily for consumer/commercial use since it relies heavily on an active IR light source for optimum performance. A major advantage over image intensifier tube systems is that the CCD cannot be damaged by normal bright light exposure. Resolution equates to approx 40 lp/mm.

5 EVALUATING THE PERFORMANCE OF A NIGHT VISION SCOPE

The very need for a night vision capability necessarily focuses on performance as the most important factor. What subjects do you need to see ? At what distance ? And in what lighting conditions ? The darker the conditions and the smaller or more distant the subject, the tougher the job gets for a night vision system. If you need to see fine details, such as car number plates/recognising an individual, especially at fairly long range, then you need to ensure that the system you are considering is capable of this.

Most Gen 1 night vision equipment available today will provide an adequate image for most non-professional requirements under higher night light conditions, such as moonlight. But, if you need to see under truly dark conditions, such as starlight, need longer range or need to see finer details then you will have to consider Super Gen 1+ or Gen 2+/SuperGen/HyperGen systems.

It is difficult to choose a night vision system by simply reading technical specifications. Not only are the performance specifications tough for most people to understand, but they are even tougher to relate to real-world use. Comparison of specifications is also only valid if test instrumentation and methodology are consistent and reliable - unfortunately, this is unlikely. The best way to evaluate a night scope is to test it in real-world conditions. Ideally, you should conduct your evaluation under the same conditions in which you intend to use the scope.

Factors to consider include:

- **Photosensitivity** - The ability of a night vision system to detect light energy and convert it to an electron image is reflected in the image intensifier's photosensitivity. Usually, the higher the value, the better the ability to "see" under darker and darker conditions. However, be aware that at night there is more light energy available in the near-infrared region than in the visible region. Therefore, if a device claims a high photosensitivity, make sure to find out where in the spectrum this is measured. A high photosensitivity in the blue, or visible, region may not perform as well as another system with a lower overall photosensitivity, but a higher value in the near-infrared region.

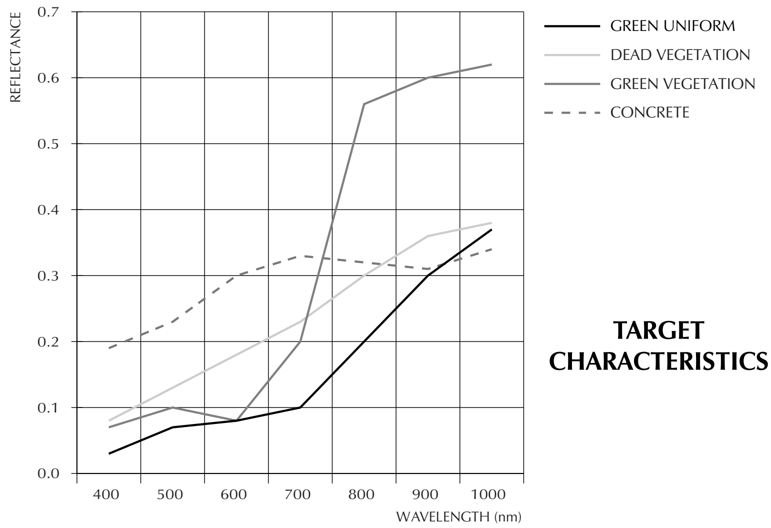
- **Gain** - This tends to be a confusing parameter when evaluating night vision devices. The darker the conditions, the harder it is for the system to render a clear image with reasonable contrast. Additional gain is required as conditions grow darker and for longer range. The most important gain measurement is the system gain. Very high gain values for an image tube are not especially significant - military devices can have tube gains ranging anywhere from 20,000 to 80,000. Look for the system gain. Military systems operate at gains in the region of 2,000 to 3,000. The higher the value the better the ability of the device to amplify the light it detects. However, if a system does not possess a good photosensitivity and SNR, a very high gain value simply means that you will make a poor image brighter, not better. Populated areas always have an atmospheric glow from artificial lighting. A high-gain device might be required in remote areas on overcast nights, but it would not be necessary for use in urban or suburban conditions. Even in isolated locations without man-made light, a high-quality, affordable Gen 1 monocular/binocular will provide good imaging with a half-moon and clear skies - this can be further enhanced with the use of an IR illuminator. The very best test is field evaluation in real-time conditions.

- **Range** - Can you see your subject 75m away? Effective range is a balanced function of the system's gain, resolution, image magnification and the amount of ambient light available. While a powerful lens will provide more image magnification, it will also reduce the amount of available light captured. The best effective range with most intensifiers is achieved with a high-speed lens that has minimal magnification (<3x). Higher levels of ambient light dramatically increase any device's range capability. Just as more gain is required for longer range in darker conditions, less gain is required as conditions grow brighter. Most applications are satisfied with systems offering image magnification of 1x to 3x. Goggles, for instance, are specifically designed for near-field viewing and use 1x image magnification to keep the wearer from becoming disoriented. For marine use, a good quality 1x magnification monocular is ideal because it gives a wide field of view - if you also need higher magnification, buy a model with interchangeable lenses. High image magnifications mean a narrow field of view and the possibility of missing a subject you are searching for.

- **Image Quality** - High resolution, high contrast and a lack of distortion and noise contribute to a premium Night Vision image. With higher resolution you might identify someone you know at 60m as opposed to simply recognizing a human figure. Superior contrast allows you to see dark subjects against darker backgrounds. Lower distortion renders a flatter, less rounded image with crisper details. Always try and choose a model that offers glass optics - these will give you the sharpest, clearest optical quality. Units that use plastic optics tend to offer lower optical quality and higher distortion.

- **Resolution** - Usually this is measured as tube resolution (lp/mm) or system resolution (cy/mr). The higher the value, the better the ability to present a sharp picture. Gen 1 devices may produce a reasonably clear image in the centre of the viewing area, but sharpness drops off noticeably toward the periphery.

• **Target Characteristics** - System performance is not only limited by intensifier/system parameters and light level, but also by the target characteristics and atmospheric conditions. To the right is a graph showing the spectral reflectance of various elements - a man in drab clothing, for instance, would stand out dark against green foliage, which is more reflective, especially in the near-infrared spectrum. The degree of contrast between the various elements visible has a lot of influence on the detectability of a subject.



TARGET CHARACTERISTICS

• **Magnification and Field Of View (FOV)** - Consider the size of your target, the distance you wish to see over and the overall area you are observing or searching. For most surveillance or search applications, the higher the magnification , the narrower the FOV & the greater the number of times you need to scan an area to avoid missing important objects or events. Usually a 1:1 lens with a wide FOV provides optimal performance. For longer range observation or weaponsight applications, the amount of magnification needed will vary; take into account that, as the magnification increases so does the lens f-number while the FOV decreases - this reduces the amount of light captured. How versatile is the device you are considering ? Do you need, and does it offer, interchangeable lenses ?

• **Ergonomics** - Size, weight and ease of use are important considerations. If you plan to carry your scope in your pocket or briefcase, then smaller systems will suit you better. Lightweight devices are more comfortable during extended viewing. Since you will be using the device in the dark, the switches and controls should be positioned logically and be easy to use.

• **Distortion** - Gen O, Gen 1, and 25-mm Gen 2 electrostatically inverted image tubes produce a certain amount of geometric distortion in the image. In Gen 2 and Gen 3 systems, geometric distortion is normally eliminated through the use of an MCP, although it is possible to encounter some perceptible S and shear distortion. Especially when the application involves photography, video work, or weaponsights, the distortion and peripheral resolution can be critical.

• **Extended Viewing** - If you intend to look through a device for extended periods of time (20+ minutes) you may find that a binocular or biocular better suits your requirements. Using a monocular continuously for this period of time will mean that your eyes will adjust individually to their lighting conditions - one to the scene through the night scope and the other to the ambient lighting. This could lead to eye strain. If you use the device for extended periods, a tripod socket may be a useful feature.

• **Weather Resistance** - The ability of a night vision system to operate under adverse environmental conditions. Most devices will withstand a light shower, but if you expect to regularly use the device in inclement weather or a marine environment, choose a model that has protection against such conditions. If you want full waterproofing, ie can be fully submersed, choose a system built to mil specs or that is guaranteed as such..

• **Practicality** - Is the battery a size and model that is commonly available? This is important, especially if you use your system in the field. All Cobra Optics/Yukon scopes use batteries that are readily available from photographic/electrical/high street retailers.

• **Reliability** - With proper care, modern Night Vision designs are relatively trouble-free. However, please be aware that intensifier tubes have a finite duty cycle (they will eventually wear out). Thomas Jackss test every single device that it sells. Every unit has to pass stringent quality checks before it is boxed for resale. Thomas Jacks Ltd sells only new Night Vision systems that incorporate protection circuitry which turns the intensifier down or off when exposed to bright light. Our intensifier tubes are conservatively rated at 1,000 hours of use under normal conditions. It should be noted, however, that any tube will degrade and eventually fail under repeated, prolonged or excessive exposure to bright light. We recommend you always cover the objective lens and store the scope properly when not using it. The image intensifier is a vacuum sealed glass tube - it can be easily damaged if the device is knocked or dropped. Ensure that you protect your scope well from such possibilities. The intensifier tube is by far the most expensive component to replace in a night scope, on average accounting for some 60-70% of the total cost.

* **Secondhand or Reconditioned Devices** - As stated above, intensifier tubes have a finite duty cycle (they will eventually wear out). Knocks, abuse or exposure to bright light will further compromise a tube's performance and life. Thomas Jacks Ltd does not supply "second hand" or "reconditioned" equipment and would not recommend the purchase of such devices unless you can be absolutely certain of their usage/performance. While the price may be attractive, be aware that the intensifier tube cannot be restored to 'new' condition. "Reconditioned" usually means the system has a new or repaired power supply, but the tube photosensitivity, SNR and the remaining life cannot be improved and will be noticeably lower than from an equivalent new device. Some second hand or reconditioned units may be operating at below acceptable minimums and few companies possess the necessary test equipment to evaluate the tube's level of performance.

• **Service** - Is the product supplied by a reputable, branded supplier, protected by a warranty that will be honoured and is technical service available ?

• **Warranty** - We offer a 1 Year Warranty on all Cobra Optics branded devices and a 3 Year Exchange Warranty on Pulsar and Yukon Advanced Optics models (unless otherwise stated). If the unit proves to have failed due to parts or labour, we will exchange it with a new device or effect repairs.

If you have a specific application in mind, but are unsure as to what equipment is best suited, Thomas Jacks Ltd is always happy to discuss your requirements and offer guidance on any suitable models.

6 APPLICATIONS

Recreational:

Wildlife Observation
Boating/Navigation
Camping/Hiking
Fishing/Hunting
Home Security
Travelling/Safaris
Stargazing/Astronomy
Study of Anomalous Phenomena

Professional:

Wildlife Study/Expeditions
Law Enforcement/Military
Farming/Land Management
Pest Control/Gamekeeping/Hunting
Security/Surveillance
Search & Rescue
Detection of Fire or Electrical Corona
Maintenance & Repair
Study of Anomalous Phenomena

7 GLOSSARY & TERMINOLOGY

Angle of View - The measure of the angle (in degrees) defining the field visible through a night vision device.

Aperture - Expressed as an f-number, this is the light gathering ability of the lens expressed as a ratio of the focal length to the lens diameter. Lower f-numbers produce brighter images - always use lenses with apertures faster than $f2.0$ for best results.

Automatic Brightness Control (ABC) - A circuit that automatically controls the phosphor screen brightness, keeping it within optimum limits and protecting the tube. The effect of this can be seen when rapidly changing from low-light to high-light conditions; the image gets brighter and then, after a momentary delay, suddenly dims to a constant level.

Binocular - A night vision binocular has two complete sets of optics and two image intensifier tubes for use with both eyes. Due to minor differences between individual tubes, focusing is independent for each optic.

Biocular - A biocular uses a single objective lens and image intensifier tube. A prism splits the image for viewing with both eyes.

Black Spots - These are either cosmetic blemishes in the image intensifier tube or can be dirt or debris between the lenses.
• Black spots that are in the image intensifier tube itself do not affect the performance or reliability of a night vision device and are inherent in the manufacturing process. Although more prevalent in the cheaper Gen 1 devices, they can still be found in Gen 2 and even Gen 3 tubes. Cobra Optics, Pulsar and Yukon have strict quality control measures and inspects every unit, rejecting those with blemishes that are too numerous, too large or those that are centred in the image field.
• Spots due to dirt or debris between the lenses can be removed by careful cleaning with quality camera cleaning supplies if the system is designed with interchangeable optics.

Blooming - A condition where the image intensifier is overloaded by a bright light source.

Bright Point Protection (BPP) - An electronic circuit that turns the power to the night vision device either down or off when it is exposed to bright light sources. This helps protect the image intensifier and extend its usable life.

Chickenwire - The hexagonal shape of some MCP fibre optic bundles may be seen as thin black lines, hence the name 'chickenwire'. Could also be confused with Shear Distortion. See also 'Fixed Pattern Noise'.

Cycles per Milliradian (cy/mr) - Units used to measure system resolution. A milliradian is the angle created by 1 yard at a distance of 1,000 yards. This means that a device that can detect two 1/2-yard objects separated by 1/2 yard at 1,000 yards has a resolution of 1.0 cy/mr. Do not confuse cy/mr with line pairs per millimeter (lp/mm). For example, a system can have a 3x lens attached and increase the system resolution by a factor of 3, but the image intensifier's resolution (measured in lp/mm) will not have increased.

Dioptre - A unit of measure used to define eye correction or the refractive power of a lens. Allows adjustment of an optical eyepiece to accommodate for differences in individual eyesight.

Distortion - Three types of distortion are most significant to night vision devices: geometric, "S", and shear.
• Geometric distortion is inherent in all Gen O and Gen 1 image intensifiers that use electrostatic rather than fibre-optic inversion of the image. Geometric distortion is eliminated in image tubes that use a microchannel plate and fibre optics for image inversion; however, some S-distortion can occur in these tubes.
• S-distortion results from the twisting operation in manufacturing fibre-optic inverters. S-distortion is usually very small and it is difficult to detect with the naked eye. Gen III image tubes manufactured to military standards since 1988 have virtually no perceptible S-distortion.
• Shear distortion can occur in any image tube that uses fibre-optic bundles (MCP's). It appears as a cleavage or dislocation in a straight line within the viewable area.
Non-inverting image intensifier tubes (mainly used in goggles) that use an MCPs and clear glass for the optics are free of distortion.

Emission Point - A steady or fluctuating pinpoint of bright light in the image area that remains even when all light is blocked from the objective lens. An emission point will remain in a fixed position within the viewable area. If an emission point disappears or is only faintly visible when viewing under brighter nighttime conditions, it is not indicative of a problem. If the emission point remains bright under all lighting conditions this may indicate damage to the intensifier tube.

Equivalent Background Illumination (EBI) - EBI is measured in lumens per square centimeter (lm/cm^2), a lower value being better. The EBI level determines the lowest light level at which you can detect something. Below this level, objects will be masked by the EBI.

Field Of View (FOV) - The measure of the angle (in degrees) defining the field visible through a night vision device.

Figure of Merit (FOM) - Measurement now being used for defining the performance of a tube. FOM=SNR x Resolution.

Fixed-Pattern Noise (FPN) - A faint hexagonal (honeycomb) pattern throughout the image. Most often occurs under high light conditions. Inherent in the structure of the microchannel plate, this can be seen in virtually all Gen 2/Gen 3 systems .

Footcandle (fc) - A unit of illuminance equal to one lumen per square foot.

Footlambert (fL) - A unit of brightness equal to one footcandle at a distance of one foot.

Gain - Also called brightness gain or luminance gain. The number of times a night vision device amplifies light input. Usually measured as tube gain or system gain. Tube gain is measured as the light output (in fL) divided by the light input (in fc). Usually seen in values of tens of thousands and more a laboratory figure that does not necessarily indicate a devices performance. If tube gain is too high, the tube will be "noisier" and the signal-to-noise ratio may go down. System gain is measured as the light output (fL) divided by the light input (also fL) and is based on the total system (ie tube, optics, power supply etc). System gain is usually seen in the low to mid-hundreds for Gen 1/Super Gen 1+ and several thousand for Gen 2/2+/SuperGen/HyperGen and Gen 3. System gain is the figure that potential night vision purchasers should compare, but be aware that different companies may use different test criteria.

Gallium Arsenide (GaAs) - A semiconductor material used in Gen 3 photocathodes. GaAs photocathodes have very high photosensitivity in the 450 to 950 nanometer spectral region.

Generation - See '4… THE GENERATION GAME'

Halo - Measurement of blooming around a bright spot of light visible by an image intensifier tube.

Infrared (IR) Illuminator - A powered light source, much like a torch, but in the near infrared range (generally 750-1000nm) that provides light for an image intensifier. Examples include light emitting diodes (LED's), incandescent bulbs and lasers - eyesafe & non-eyesafe. Infrared light is normally invisible to the human eye, but a red glow may be visible from the illuminator's diode. Fully covert IR illuminators are available, but can only be 'seen' by Gen 3 or digital systems. Many budget-priced commercial night scopes come supplied with a short-range LED IR Illuminator to enhance performance in low light/total darkness. All IR illuminators are 'active' and can clearly be seen by anyone else equipped with a night scope. Be careful when using IR illuminators, especially lasers - their extremely concentrated high power beams can burn/damage image intensifier tubes.

Line Pairs per Millimeter (lp/mm) - A unit used to measure image intensifier resolution.

Lumen - A unit of measurement denoting the photons perceivable by the human eye in one second.

Maximum Relative Viewing Range - To express any sort of range performance, you must delineate the criteria that is used for the measurement - are you trying to see a fox, a man or an elephant and in what lighting conditions ? As expressed by Cobra Optics, and purely for comparison of their own devices, this is based on a man-sized object in good moonlight conditions. If there is less than good moonlight or the object being viewed is smaller than a man, maximum range should be reduced accordingly. Performance will drop off most noticeably with budget Gen 1 systems as these factors reduce. Note that some suppliers use different criteria or do not quote the criteria their range claim is based upon.

Microamperes per Lumen (μA/lm) - The measure of electrical current (μA) produced by a photocathode when it is exposed to a measured amount of light (lumen).

Microchannel Plate (MCP) - A thin metal-coated glass disk that multiplies the electrons produced by the photocathode. An MCP is found only in Gen 2/2+/SuperGen/HyperGen and Gen 3 systems. MCPs consist of an array of glass (fibre optic) channels (anywhere from 2 to 6 million). In the best quality MCP's the diameter of each channel can be 4-6μm. Electrons entering a channel strike the wall and knock off secondary electrons which in turn knock off even more electrons producing a cascading effect - this can result in the production of several thousand times the input number. MCP's eliminate the distortion characteristic of Gen O/Gen I systems, giving edge-to-edge definition and making devices using them most suitable for photographic/video applications.

Milliamps per Watt (mA/W) - The measure of electrical current (mA) produced by a photocathode when exposed to a specified wavelength of light at a given radiant power (watt). As with microamperes per lumen, generally, the higher the value, the better the performance; however, it is important to know where in the spectrum the wavelength falls. Because light at night is primarily in the near-infrared spectrum (some 70%), a high value in the blue regions (400-750nm) is not as good as a moderate value in the near-infrared (750-1000nm).

Monocular - A night vision device for use with one eye.

MTTF - Mean Time To Failure - the expected lifespan of a tube based on use in starlight conditions.

Multi-Alkali - A semiconductive coating for Gen 1 and Gen 2 photocathodes.

Nanometer (nm) - Unit of measurement for electromagnetic energy.

Near-Infrared - The shortest wavelengths of the infrared region, nominally 750 nanometers to 1μm. Gen 1 operates from around 300 to 830nm. Gen 2 operates from around 400 to 870nm. Gen 3 and digital NV operate from around 450 to 940nm.

Noise - A faint sparkling effect throughout the night vision image. Also called video noise or scintillation. It's presence can indicate that the system is struggling to amplify what little light is available.

Phosphor Screen - Positioned at the rear of the intensifier tube, the phosphor screen flouresces when hit by the flow of electrons within the tube and gives us a visible image. Because it is flat, it gives little or no depth perception. Green phosphor is used because the human eye can detect more contrast in green than any other phosphor colour.

Photocathode - The input surface of an image intensifier that absorbs light energy (photons) and converts it to electrical energy (electrons). Different combinations of photocathode and input window materials can affect spectral response characteristics.

Photonic Spectrum - The range of electromagnetic energy from 0.1nm (x-ray) to 100μm (far-infrared). Within this range is the visible band from 400-750nm and near-infrared from 750nm-3μm.

Photoresponse (PR) - See Photosensitivity.

Photosensitivity - The ability of the photocathode material to produce an electrical response when subjected to light waves (photons). Usually measured in microamperes per lumen (μA/lm). The higher the value, the higher the capability of producing a visible image in dark conditions.

Resolution - The ability of an image intensifier or night vision system to distinguish between objects close together. Image intensifier resolution is measured in line pairs per millimeter (lp/mm) while system resolution is measured in cycles per milliradian. For any particular night vision system, the image intensifier resolution will remain constant while the system resolution can be affected by altering the objective or eyepiece optics or by adding magnification, relay lenses, filters etc. The resolution can be noticeably different when measured at the centre of the image and at the periphery. This is very important for devices selected for photography or video where the edge-to-edge image resolution is important.

Signal-to-Noise Ratio (SNR) - A measure of the light signal reaching the eye divided by the perceived noise as seen by the eye. A tube's SNR determines the low-light-resolution of the image tube; therefore, the higher the SNR, the better the ability of the tube to resolve objects with good contrast under low-light conditions. Normally only quoted on mil spec devices.

Scintillation - A faint, random, sparkling effect throughout the image area. This is a normal characteristic of image intensifiers fitted with a microchannel plate (MCP). Most noticeble under the lowest light levels, it is sometimes called "video noise". Do not confuse scintillation with emission points.

Spectrum - See Photonic Spectrum.

Wavelength - Electromagnetic energy is transmitted in the form of a sinusoidal wave. Wavelength is the physical distance covered by one cycle of the wave. In the photonic spectrum, wavelength is measured in nanometers (nm) and micrometers (μm).

8 PRECAUTIONS

• NEVER turn a night vision scope on in daylight or toward bright light sources at night (such as car headlights/ street lights/infra red illuminators) without the lens cap on. This can cause permanent damage to the intensifier tube and will void the guarantee.

• DO NOT attempt to open the body of a night vision scope. High voltage is present and there are no user serviceable parts.

• DO NOT jar or shock the unit. Mishandling will void any guarantee.

• DO NOT expose your night scope to water. Although resistant to light showers, most night vision scopes are not Weather/Water Resistant unless quoted as such. Very few night vision scopes are fully waterproof, ie submersible, unless stated as such.

• PROTECT the scope from direct sunlight, extreme heat, dust, moisture and sudden changes in temperature. If condensation is visible, leave the scope in a warm room and do not operate for several hours.

• STORE your night scope in a dry, warm, ventilated room.

• ALWAYS clean the lens and eyepiece with high quality camera cleaning equipment. To clean the exterior of the scope use only a soft, clean cloth.

IF YOU NEED ADVICE OR FURTHER INFORMATION ON ANY ASPECT OF NIGHT VISION, PLEASE DO NOT HESITATE TO CONTACT THE COBRA OPTICS/YUKON HELPLINE USING THE CONTACT DETAILS BELOW. WE WILL DO OUR BEST TO ANSWER YOUR QUERIES.

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