APPENDIX D

NIGHT VISION PRINCIPLES

Vision is the most important sense you use while driving. It makes you aware of the position of your vehicle in relation to the road. You need good depth perception to determine height and distance, good visual acuity to identify terrain features and obstacles that lie along the road and good night vision techniques to be efficient in night operations. When driving during daylight hours, eyes can rapidly identify and interpret visual clues. During hours of darkness, however, illumination is reduced, and vision is limited. Wheeled vehicle operators with 20/20 daylight vision may not have adequate night vision.

To increase your capability to operate at night, you must understand night vision principles and the use of night vision techniques for viewing at night. This appendix includes information about the anatomy of the eye, types of vision, visual problems that affect night vision, differences between day and night vision, target detection, dark adaptation, night vision scanning techniques, distance estimation and depth perception visual illusions, measures used to protect night vision, self-imposed stresses, the effect of nerve agents on night vision, sources of ambient light and meteorological considerations.

EVALUATION OF NIGHT VISION

Your ability to drive at night is based on your ability to see at night and how well you train your night vision. Although the limits of night vision vary from person to person, most drivers never learn to use their night vision to its fullest capacity. A person with average night vision who uses night vision techniques is more effective than someone with superior night vision who does not use these techniques.

ANATOMY AND PHYSIOLOGY OF THE EYE

The eye is similar to a camera. The cornea, lens, and iris combination gathers and controls the amount of light that enters the retina (Figure D-l).

The parts of the eye are described as follows:

- The CORNEA is a transparent tissue covering the front of the eye like a watch crystal covers a watch. (Contact lenses are fitted over the cornea.)
- The IRIS is a thin circular curtain which is the colored part of the eye. A person's eye color depends on the amount of pigment in the iris. Light blue has the least amount and dark brown the most.
- The PUPIL is a hole in the center of the iris. It is black because the inside of the eye is dark. The size varies with the amount of light entering the eye. It gets smaller with increased light.
- The LENS is a transparent, semisoft material about half the size of a dine. It can change shape to focus on objects at different distances from the eye.
- The RETINA is the lining at the back of the eye where the image is formed. It consists of rod cells, which see black and white, and cone cells, which see colors. The picture seen by the retina is sent to the brain along the optic nerve.

Light enters your eye through the pupil. The iris controls the amount of light entering the eye. The light passes through the lens which focuses it onto the retina at the back of the eye. The picture seen by the retina is upside down the brain turns it right side up. The brain gets a slightly different picture from each eye and usually combines them to make one picture.

TYPES OF VISION

There are three types of vision. Each type requires different sensory perceptors to identify an image.

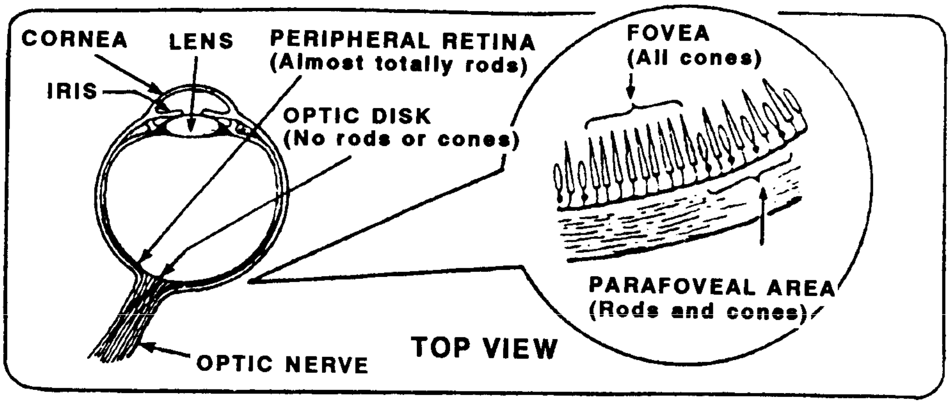

FIGURE D-1. Anatomy of the Eye.

Photopic Vision

Photopic vision is experienced during daylight hours or when a high level of artificial light exists. Under these conditions, sight is achieved primarily by the cones, especially those concentrated in the fovea. Due to the high light condition, rod cells are bleached out and become less effective. Sharp image interpretation (fine resolution of detail) and color vision are characteristic of photopic vision. Under these conditions, objects are detected with peripheral vision but are viewed primarily with central (foveal) vision.

Mesopic Vision

Mesopic vision is experienced at dawn and dusk and during periods of mid-level light. Vision is achieved by a combination of the rods and cones. Visual acuity steadily decreases; the available light decreases. A reduction in color vision occurs as the light level decreases; the cones become less effective. Due to gradual loss of cone sensitivity, greater emphasis is placed on off-center vision and scanning to detect objects.

Scotopic Vision

Scotopic vision is experienced in low-level light conditions. Cone cells become ineffective causing poor resolution of detail. Visual acuity decreases to 20/200 or less. Color perception is totally lost. A central blind spot occurs due to the loss of cone sensitivity. Objects must be viewed using off-center viewing and scanning. The natural reflex of looking directly at an object must be reoriented by night vision training. The use of scotopic vision demands searching movements of the eyes to locate an object and small eye movements to keep the object in sight. Characteristically, in this type of vision a dim image may fade away if your eyes are held stationary for more than a few seconds.

VISUAL PROBLEMS AFFECTING NIGHT VISION

Two visual deficiencies that may become more apparent at night are presbyopia and night myopia. Another visual problem that affects night vision is astigmatism.

Presbyopia

This deficiency, which commonly occurs in individuals over 40 years of age, is due to hardening of the lens. It involves a loss of the eye's ability to focus diverging light rays from near objects. As a result, light transmission from the lens to the retina decreases light scattering or glare increases. As presbyopia increases, instruments, maps, and checklists become more difficult to read, especially in red light. Certain types of bifocal lenses that compensate for this condition can correct this deficiency.

Night Myopia

At night, the spectrum of available light changes; blue wavelengths of light are dominant. Therefore, a person who is slightly nearsighted (myopic) will find it hard to see at night; blurred vision could occur. Special lenses can be prescribed to correct myopia.

Astigmatism

Astigmatism is an irregularity of the eye that produces an out-of-focus condition. For example, if you focus on power poles (vertical), the wires (horizontal) will be out of focus in most cases. The typical prescription for glasses is written showing three numbers for each eye. The first number is the spherical portion of your prescription, which can be compensated for by NVGs. The second number is the astigmatism in degrees, and the third number is the axis of the astigmatism in degrees.

DIFFERENCES BETWEEN DAY AND NIGHT VISION

Color

One way night vision differs from day vision is in color vision. As light levels decrease, the eyes shift from photopic vision (cones) to scotopic vision (rods). With this shift, the eyes become less sensitive to the red end of the spectrum and more sensitive to the blue part of the spectrum. Color perception is not possible with the rods. Colors of nonlighted objects cannot be determined at night under very low light conditions. You can distinguish between light and dark colors at night only in terms of the brightness of reflected light. If, however, the brightness of a color is above the threshold for cone vision, the color can be seen.

Detail

Perception of fine detail is impossible at night. Low light conditions greatly reduce visual acuity. At 0.1 footcandle (level of full moonlight), acuity is one-seventh as good as it is in average daylight. Therefore, objects must be rather large or nearby to be seen at night. Identification at night must depend on the perception of generalized contours and outlines and not on small distinguishing features.

Retinal Sensitivity

Another important distinction between night vision and day vision is the difference in the sensitivity of various parts of the retina under these two conditions.

The central part of the eye is not sensitive to starlight levels. During darkness or with low-level light, central vision becomes less effective, and a relative blind spot (5 to 10 degrees wide) develops. This is due to the concentration of cones in the area immediately surrounding the fovea of the retina.

Since the central fields of vision for each eye are laid over each other for binocular (two-eyed) vision, a night blind spot occurs during periods of low-level illumination. If an object is viewed directly, it may not be detected because of this blind spot (Figure D-2).

Because of the central blind spot, as distance increases, larger and larger objects will not be seen. To see things clearly at night, use off-center vision and scanning techniques.

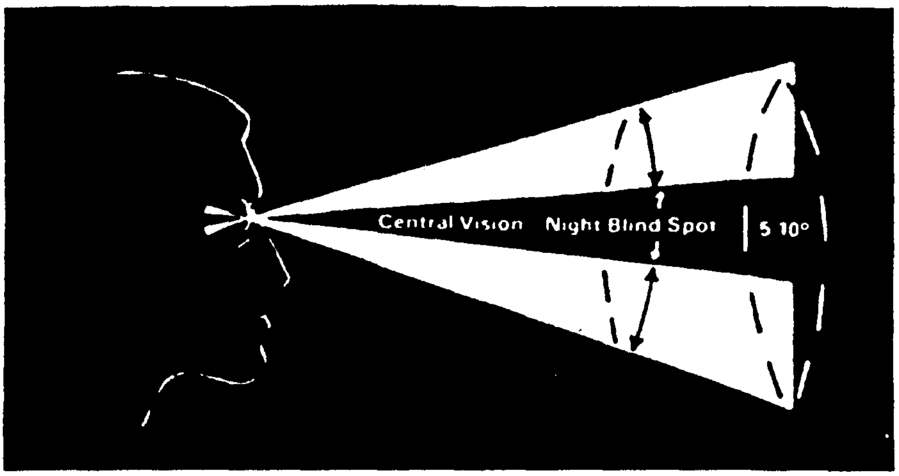

FIGURE D-2. Night Blind Spot.

TARGET DETECTION

With 20/20 vision detection of a target depends on several factors including–

- Target size and distance (relative target size).
- Overall brightness (luminance).
- Brightness and color contrast between target and background.
- Location of eye focus.
- Angle between central visual axis and target.

DARK ADAPTATION

Dark adaptation is the process by which your eyes increase their sensitivity to low-light levels. People dark-adapt to varying degrees and at different rates. During the first 30 minutes, the sensitivity of the eye increases roughly ten thousandfold, with little further increase after that time.

Going suddenly from bright light into darkness occurs often; for example, when you enter a movie theater during the day or leave a brightly lit room at night. In both cases, the sensations are the same. At first you see very little, if anything. After several minutes you can see dim forms and very large outlines. As time passes you see more details of the surroundings.

The lower the level of light, the more rapidly you complete dark adaptation. For example, you need less time to completely dark-adapt after being exposed to a darkened theater than after being exposed to the brightness of day.

Maximum dark adaptation is reached in 30 to 45 minutes under minimal lighting conditions. If the dark-adapted eye is exposed to a bright light, the sensitivity of that eye is temporarily impaired. The amount of impairment depends on the intensity and duration of the exposure. Exposure to a flare or lightning may seriously impair your night vision. Recovery to dark adaptation could take from 5 to 45 minutes in continued darkness.

Night vision goggles affect dark adaptation. If you dark-adapt before donning the goggles and remove them in a darkened environment, expect to regain full dark adaptation in 2 to 10 minutes.

NIGHT VISION SCANNING TECHNIQUES

Dark adaption is only the first step to maximize your ability to see at night. Applying night vision techniques will help you to overcome many of the physical limitations of your eyes.

Scanning techniques are important to identify an object at night. To scan effectively, scan from right to left or left to right using a slow, regular scanning movement (Figure D-3).

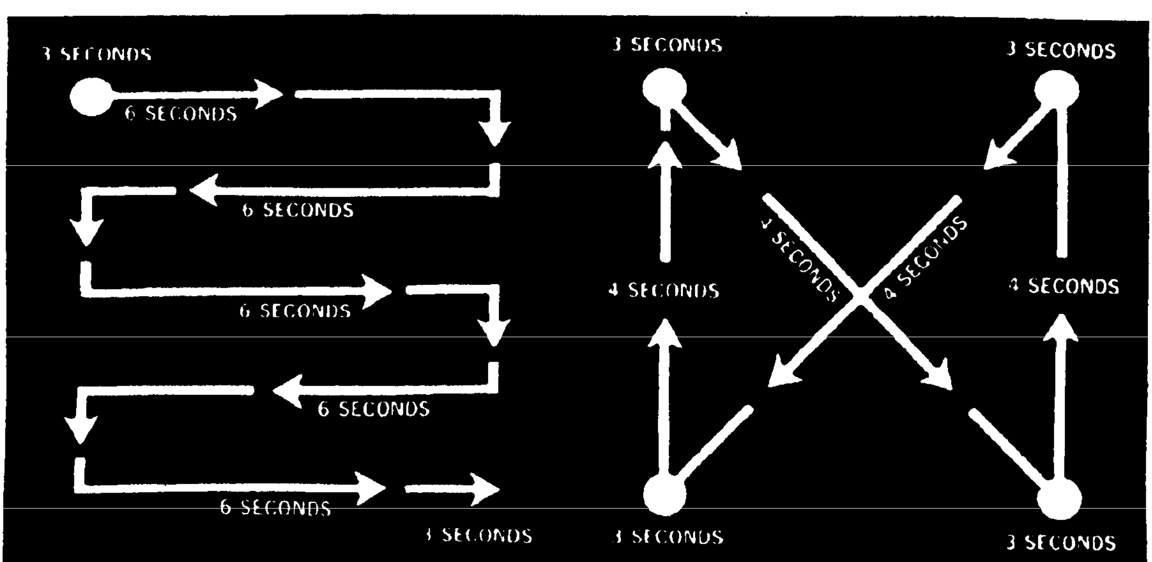

FIGURE D-3. A Typical Scanning Pattern.

Viewing an object using central vision during daylight poses no limitation. If you use the same technique at night, you may not see the object. This is due to the night blind spot that exists during periods of low light. To makeup for this limitation use off-center vision. This technique requires you to view an object by looking 10 degrees above, below, or to either side of, rather than directly at an object. This lets your peripheral vision maintain contact with an object.

Even when off-center viewing is practiced, the image of an object viewed longer than 2 to 3 seconds tends to bleach out and become a solid tone. As a result, the object is no longer visible. This produces a potentially unsafe operating condition. To overcome this limitation, be aware of the phenomenon. Avoid looking at an object longer than 2 or 3 seconds.

Visual acuity is greatly reduced at night. Therefore, objects must be identified by their shape or outline. Your familiarity with the architectural design of the structures common to the area will determine your success using this technique, For example, the outline of a building with a high roof and a steeple can be easily recognized in the United States as a church. Churches in other parts of the world may have entirely different distinguishing features. Man-made features depicted on your map can help you recognize outlines during night driving,

DISTANCE ESTIMATION AND DEPTH PERCEPTION

Distance estimation and depth perception clues are easily recognized using central vision during periods of good lighting. But as light levels decrease, your ability to correctly judge distances decreases, and you tend to have visual illusions. A knowledge of distance estimation and depth perception clues will help you to better judge distance at night.

Distance and depth perception clues may be monocular (one-eyed) or binocular (two-eyed). The binocular clues depend on the slightly different view each eye has of the object. Consequently, binocular perception is useful only when the object is close enough to make the viewing angle of the two eyes obviously different. Because they are rarely improved by study and training, binocular clues are not discussed here. Monocular clues used to help distance estimation and depth perception are discussed below.

Geometric Perspective

An object has an apparent different shape depending on the distance and angle from which it is seen (Figure D-4). Geometric perspective clues include linear perspective, apparent foreshortening vertical position in the field, and motion parallax.

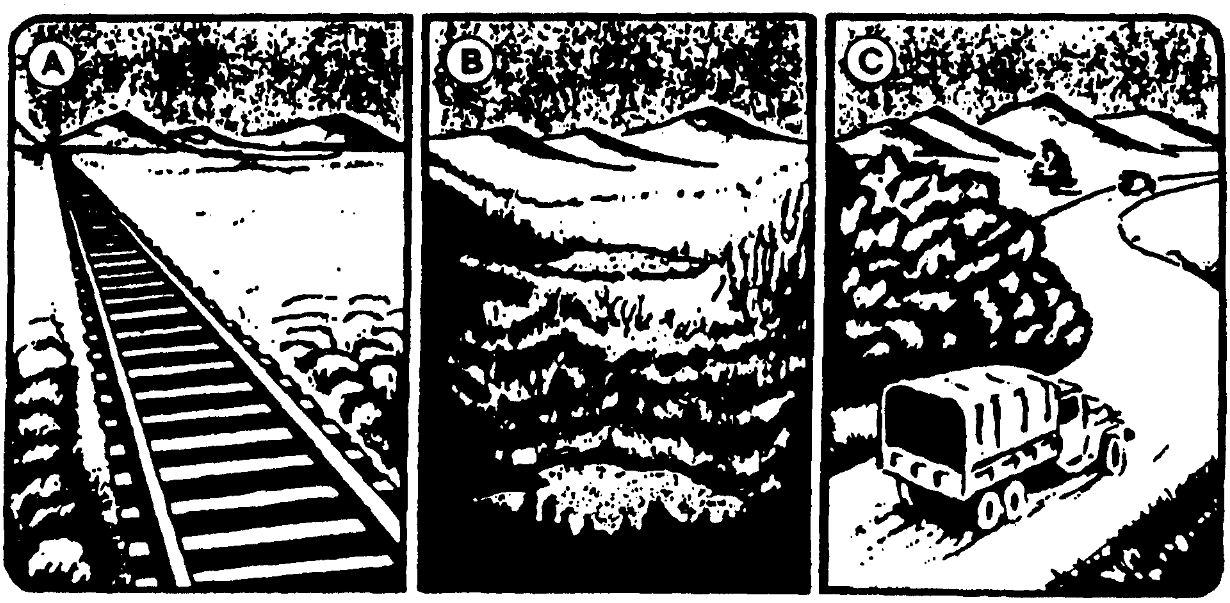

FIGURE D-4. Geometric Perspective.

Linear Perspective. Parallel lines such as railroad tracks or runway lights (Figure D-4A) tend to converge as distance from the observer increases.

Apparent Foreshortening. The true shape of an object or terrain feature seems oval when seen from a distance. As the distance to the object or terrain feature decreases, the apparent perspective changes to its true shape or form. Figure D-4B illustrates how the shape of a body of water changes when viewed at different distances at the same altitude.

Vertical Position in the Field. Objects or terrain features at a distance from the observer seem higher on the horizon than objects or terrain features that are closer to the observer. The highest vehicle in Figure D-4C looks the closest to the top and is judged to be the greatest distance from the observer.

Motion Parallax. This clue to depth perception is often considered the most important. Motion parallax is the apparent relative motion of still objects as seen by an observer moving across the landscape. Near objects seem to move backward, past, or opposite the path of motion. Far objects seem either to move in the direction of motion or remain fixed. The rate of apparent movement depends on the distance the observer is from the object. For example, as you drive along a road, a picket fence whizzes by while a tree further away from the road passes more slowly. Mountains in the distance seem to be freed or to move with the vehicle.

Retinal Image Size

The brain perceives the size of an image focused on the retina to be a certain size. To determine distance using the retinal image, consider three factors: known size of objects, increasing / decreasing size of objects, and land associations.

Known Size of Objects. The nearer an object is to the observer, the larger its retinal image. The brain learns from experience to associate the distance of familiar objects by the size of their retinal image. A structure will fix a specific angle on the retina based on the distance from the observer. If the angle is small, the observer judges the structure to be at a great distance. If the angle is large, the building is judged as being close. To use this clue, you must know the actual size of the object and have seen it before. If you have not seen it before, determine an object's distance primarily by motion parallax.

IncreasinglDecreasing Size of Objects. If the retinal image size of an object increases, it is getting closer. If the image size decreases the object is moving farther away. If the image size is constant, the object is at a fixed distance.

Land Associations. Comparing an object, such as a motor pool, with an object of known size, such as a 5-ton truck will help determine the object's relative size and apparent distance from the observer. Objects ordinarily associated together are judged to be about the same distance.

VISUAL ILLUSIONS

As visual information decreases, the probability of spatial disorientation increases. Reduced visual references also create illusions that can cause spatial disorientation.

Autokinesis

When a person stares at a still light in the dark, the light seems to move. This occurrence can be rapidly demonstrated by staring at a lighted cigarette in a dark room. Apparent movement will start after 8 to 10 seconds. Although the cause is not known, it seems to be related to the loss of surrounding references that normally serve to stabilize your visual perceptions. This illusion can be eliminated or reduced by visual scanning, increasing the number of lights, or varying the brightness of the light. The most important of the three solutions is visual scanning.

Relative Motion

A person sitting in a car at a railroad crossing waiting for a train to pass often experiences the illusion of relative motion. Even though the car is not moving, the person feels that it is moving. The only way to correct this illusion is to understand that such illusions do occur and to not react to them on the vehicle's controls. Using proper scanning techniques can help prevent this illusion.

Reversible Perspective Illusion

A vehicle may seem to be moving away when it is in fact approaching you. This illusion is often experienced when a vehicle is driving parallel to your course. To determine its direction, watch its lights. If the brightness of the lights increases, the vehicle is approaching you. If the lights dim, the vehicle is retreating.

Structural Illusions

Heat waves, rain, snow, sleet, or other factors that block vision cause structural illusions. For example, a straight line may appear to be curved when seen through a desert heat wave.

Size-Distance Illusion

This illusion results from staring at a point of light that approaches and then retreats from the observer. Instead of seeing the light advancing or receding, the lights may seem to expand and contract at a fixed distance. Without additional distance clues, accurate range estimation is extremely difficult. Using proper scanning techniques can help prevent this illusion.

NIGHT VISION PROTECTION

Night vision should be protected whenever possible. There are various precautions you can take.

Sunglasses

Repeated exposure to bright sunlight has an increasingly negative effect on dark adaptation. This effect is intensified by reflective surfaces, such as sand and snow. Exposure to bright sunlight for 2 to 5 hours definately decreases your scotopic visual sensitivity for as long as 5 hours. Additionally, your rate of dark adaptation and degree of night vision will decrease. These effects combine with each other and may persist for several days.

If night driving is expected, use military neutral density (N-15) sunglasses or equivalent falter lenses when exposed to bright sunlight. This precaution will maximize your rate of dark adaptation at night and improve your night vision sensitivity.

Night Tactical Operations Precautions

During a night tactical mission, expect to experience battlefield condition such as artillery flashes, flares, and searchlight as well as oncoming vehicle headlights and lightning. These conditions will cause total or partial loss of your night vision. When you are confronted with these conditions, use the following techniques:

- If a flash or high-intensity light is expected from a certain direction, turn the vehicle away from the light source. When such a condition occurs unexpectedly and cannot be avoided, save your dark adaptation by closing one eye. Once the light source is no longer a factor, the eye that was closed will provide enough night vision to continue driving. This is possible because dark adaptation occurs independently in each eye. Viewing with one dark-adapted eye, however, will cause depth perception problems.

- Select routes to avoid built-up areas with heavy concentrations of light. If you encounter these conditions, alter your route to avoid brightly lighted areas. A decrease in dark adaptation from a single light source, such as a farmhouse or an automobile can be reduced; turn your head and eyes away from the light.

- When flares are used to light the viewing area or if they are set off near your position, maneuver the vehicle away from the flare to the edge of the lighted area Thus your exposure to the light source is minimized.

- Use short bursts of fire when firing automatic weapons. Close one eye or look away from the firing to minimize loss of dark adaptation.

SELF-IMPOSED STRESSES

Many self-imposed stresses limit night vision. Be aware of these restrictions to ensure that you avoid them before driving at night.

Smoking

Smoking significantly increases the amount of carbon monoxide carried by the hemoglobin of red blood cells. This reduces the blood's ability to combine with oxygen. The smoker effectively loses 20 percent of his night vision at sea level.

Alcohol

Alcohol is a sedative that impairs coordination and judgment. As a result, you will fail to apply the proper night vision techniques. You begin to stare at objects, and your Scanning techniques become disorganized.

Fatigue

You will not be mentally alert if you are tired when performing night driving. Your response to night situations that require immediate reaction will slow down. Depending on the degree of fatigue, your performance may become a safety hazard.

Nutrition

Missing or postponing meals can negatively affect night driving performance. The resulting hunger pains cause unpleasant feelings, distraction, breakdown inhabit pattern, shortened attention span, and other physical changes.

Failure to eat foods that provide sufficient vitamin A can reduce night vision. Food high in vitamin A include eggs, butter, cheese, carrots, squash, peas, and all types of green vegetables. A balanced diet normally provides an adequate amount of vitamin A. Excess amounts of vitamin A will not increase your night vision ability and may be harmful.

Physical Conditioning and Sleep and Rest Requirements

Because of the physical stresses of night driving, you will tire more easily. To overcome this, exercise daily. Good physical fitness will help you conduct night driving with less fatigue and will improve your night scanning efficency. However, too much exercise in one day may leave you too tired for night driving.

Night driving is more tiring and stressful than day driving. Therefore, get adequate rest and sleep before driving.

NERVE AGENTS AND NIGHT VISION

Exposure of the eyes to very small amounts of nerve agents negatively affects night vision. Chemical alarms are not sensitive enough to detect the low levels of nerve agent gas that can cause miosis (contracting of the pupils). Miosis may occur gradually through exposure to low levels of nerve agent gas over a long period of time. However, exposure to a high level can cause miosis in the few seconds it takes to put on a protective mask.

The onset of miosis is tricky in that it is not always immediately painful. Miotic subjects may not realize their condition even when carrying out tasks requiring vision in low ambient light. After an attack by nerve agents, especially the more lasting types, commanders should assume there will be some loss in night vision among personnel otherwise fit for duty. No drug can cure the effects of miosis without causing other visual problems that may be just as severe.

SOURCES OF AMBIENT LIGHT

Sources of ambient light include the moon, background illumination, artificial light, and solar light.

The Moon

The moon provides the greatest source of ambient light at night. It rises in the east and sets in the west. The time at which it rises and sets changes continually. The moon angle changes approximately 1.5 degrees per hour (1 degree every 4 minutes). Light from the moon is brightest when the moon is at its highest point.

Background Illumination

Natural light sources provide background illumination at night. Besides the light provided by the sun and moon, the following natural light sources add to night brightness:

- Airglow (also called night-sky luminance).
- Aurora (also called Northern Lights in the Northern Hemisphere and Southern Aurora in the Southern Hemisphere).
- Starlight.
- Zodiacal light (also called counterglow).

Artificial Light

Lights from cities, automobiles, fires, and flares normally are sources of small amounts of artificial light. The lights of a large metropolitan area will, however, increase the light level around the city. The light from these sources is most pronounce-d in overcast conditions.

Solar Light

Ambient solar light is usable for certain periods following sunset and before sunrise. After sunset, solar light steadily decreases until the level of light is not usable to the unaided eye. This occurs when the sun is 12 degrees below the horizon. Before sunrise, solar light becomes usable when the rising sun is 12 degrees below the horizon.

METEOROLOGICAL CONSIDERATIONS

Atmospheric conditions can affect hemispherical illumination. Because weather conditions vary, light levels cannot always be accurately predicted. An awareness of these factors will help to evaluate the available ambient light. Some meteorological conditions that restrict hemispherical illumination are discussed below.

Due to reduced vision at night, you may fail to detect a gradual increase in cloud coverage. At night, you must be alert for the following indications that clouds are present:

- A gradual reduction in light level.
- Obscuration of the moon and stars.
- Shadows resulting in varying levels of ambient light.

Humidity reduces transmission of light through the atmosphere. When humidity is high, ambient light is greatly reduced High dew point temperatures indicate high humidity. An increase in the humidity content of the air will decrease the brightness of ground lights.

Restrictions, such as fog, dust, haze, or smoke, reduce hemispherical illumination. These conditions are greater at lower altitudes and intensify as temperatures decrease and the dew point spread approaches zero.

At least one weather occurrence INCREASES illumination. Lightning flashes have an effect similar to that of a bright flare. The brightness of the illumination depends on the closeness of the thunderstorm.