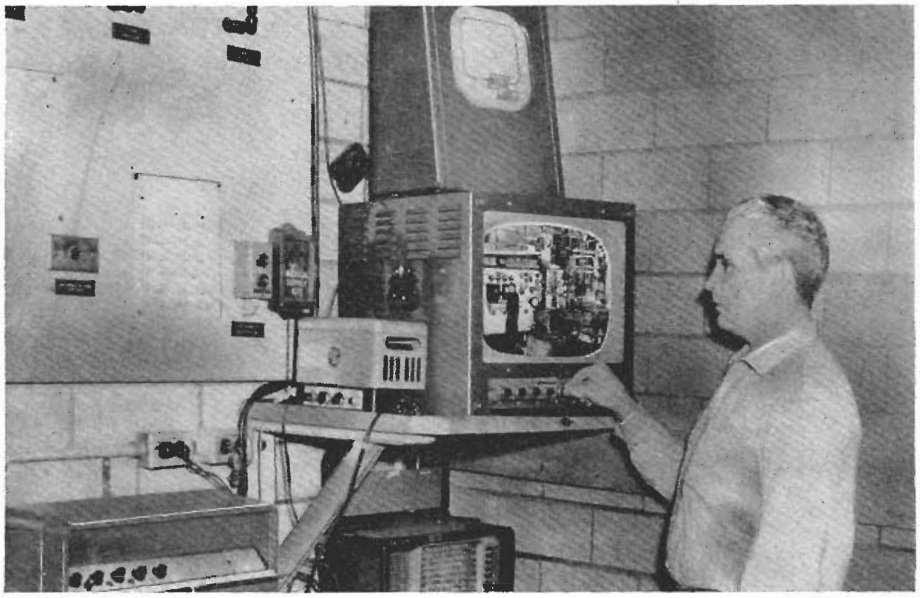
ITV Lens and Lighting Systems



Shift foreman at Esso Research & Engineering Co. pilot plant at Bayway, N. J., checks safety of workmen on job at unit 300 feet away via General Precision Labs closed-circuit TV system.

By EDWARD M. NOLL

LIGHT and lenses are important factors if you want a good quality picture from an industrial television system. Last month we learned of the importance of careful camera tuning. The same thoughtful attention should be given to the choice of camera lens, camera placement and lighting.

Camera placement is important. Experiment before deciding on a final mounting position. An optimum compromise should be made between mounting position, information to be conveyed and available lighting. The mounting position should be so selected that it does not interfere with the operation of the device being observed or with regular traffic activities in the plant or business establishment.

The camera should be rigidly mounted and the mount used must withstand whatever temperature or weather variables exist. Many special mounts are available. There are explosion-proof mounts as well as completely weather-proofed ones for outdoor application. Special mounts for microscopes, data pickup and other instrumentation uses are available. One of the most versatile is the motor-controlled pan and tilt arrangement. With such an installation the camera can scan a given area and be tilted up and down from a remote master viewing position.

All these factors should be considered by the installer and made known to the potential owner of an industrial TV system. The owner may want a camera for one particular operation. However, other tasks can also be handled by the installation if the mounting positions and mounting devices are chosen carefully. Always keep this in mind and bring it to the owner's attention as you survey the area in which the installation is to be made. For example, a camera may be needed to observe a particular confined operation during the plant's operating hours. However, there is no reason why the same camera can't be used for plant surveillance and protection at night.

A closeup lens can be used to pick up the specific industrial procedure during plant operation and a wide-angle lens can be switched in at night. Then proper pan and tilt adjustments can be made so the camera covers a much larger area for surveillance.

In some installations, it may not be possible to use supplemental lighting and it may be necessary to pick up a picture with a low ambient light level. Under these conditions, the camera should be mounted close to the monitored area to make full use of whatever light is available. A fast, high-sensitivity lens is a necessity. Of course, the lens iris should be opened wide to admit as much light as possible. In other installations the camera may face a flame, molten metal or other intense light source. If this happens, use neutral-density filters in front of the light source or camera lens to cut down the light level. It is usually better to put the filter in front of the light source so adjacent objects will be reproduced with better contrast.

Lenses and their characteristics

The choice of lenses for a given industrial television application is a function of a number of factors. Lens diameter and focal length must be chosen to produce an image on the very tiny photosensitive area of the vidicon target. The lens chosen must render the proper field of view and depth of focus to include all the desired material in the picture. The desired viewing area should fill the useful picture area to produce a discernible and high-resolution picture.

To understand more clearly how a wise lens choice can be made, let us consider the four major characteristics of lenses: focal length, lens speed, field of view and depth of focus. The focal length of a lens, as shown in Fig. 1, is the separation between the optical center of the lens and the point where the parallel rays come into focus. With the proper focal length, the desired subject or viewing area produces an image that just fills the target area of the vidicon tube. In turn, the image on the monitor screen just fills the picture-tube raster in the same proportion. The focal length of a lens is designated by a capital F (not to be confused with f, which we shall meet later). The greater the F number, the wider the separation between lens and vidicon and, therefore, the greater the physical length of the lens barrel.

Actually, the F of a lens determines image magnification and the field of view that can be covered. A large-F lens gives a better closeup view of a

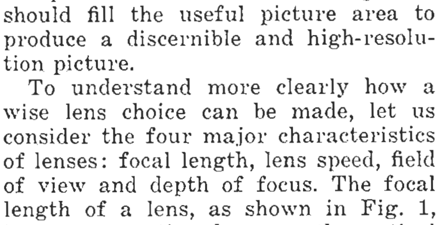
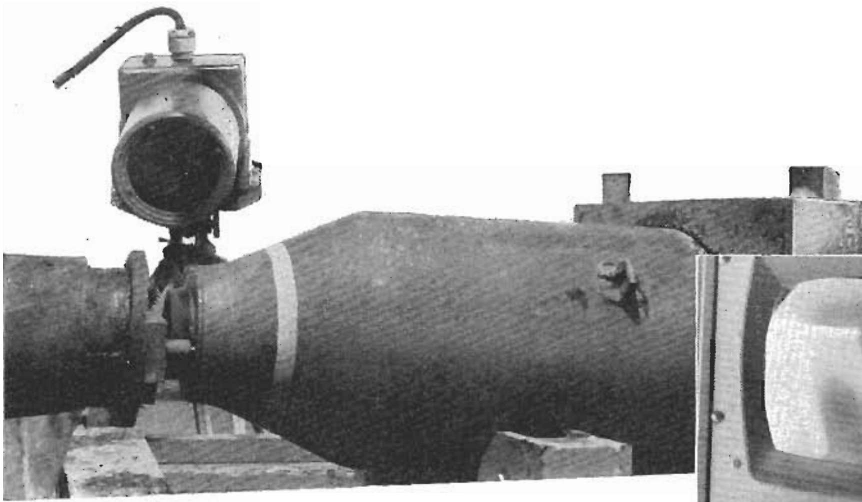


Fig. 1—Simple diagram shows lens characteristics.



This pair of photos shows the camera and monitor installations at a US Army bomb disposal site. The G-E camera is mounted in an explosion-proof case.

distant object. However, the horizontal and vertical viewing fields of a large-F lens are smaller. This relationship can be best shown by the chart in Fig. 2.

The chart indicates the horizontal field of view (width) at various distances from the lens in terms of the focal length of the various standard lenses that can be employed in industrial television service. Notice the field of view for a 1-inch lens at 20 feet is 10 feet wide. A 2-inch lens has only a 5-foot field of view at 20 feet. The

$$\frac{F}{\omega} = \frac{D}{W}$$

$$W = \frac{D\omega}{F}$$

$$W = \frac{20 \times \frac{1}{2}}{2} = 5 \text{ feet}$$

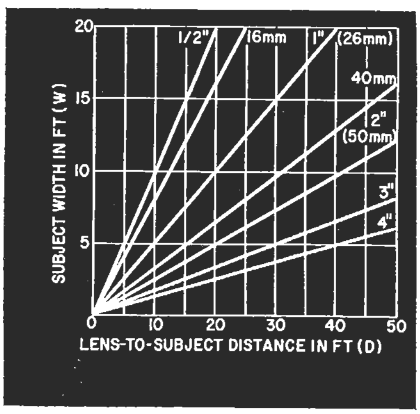


Fig. 2—Lens chart showing subject distance and field of view. Characteristic lines for several lenses are shown.

relationship can be stated as a formula: where W equals subject width in feet, D equals lens-to-subject distance in feet, ω equals vidicon target width in inches, and F the focal length of the lens in inches.

Target dimensions of the vidicon tube are ½ inch wide by ⅜ inch high, establishing the standard 4-to-3 aspect ratio. As a result, the vertical field of view is actually three-fourths of the value indicated on the chart and as calculated in the previous example. For example, the vertical field of view with the calculated horizontal field of view of 10 would be 7.5 feet. For a horizontal field of view of 5 feet, the vertical field would be 3.75 feet. Typical fields of view for the 1-, 2- and 3-inch, etc., lenses are shown in Fig. 2.

In other words, choose a lens whose focal length can accommodate the field of view desired at the prescribed distance from the camera. The installer, with the help of a lens chart, determines what type of lens to use to cover the desired area with relation to the camera mounting position.

Lens speed also has great significance. Lens speed is indicated by a small f number and is related to the focal length and lens diameter:

$$f = \frac{F \text{ (focal length)}}{D \text{ (lens diameter)}}$$

A large-diameter lens admits more light, is more sensitive and is said to be faster. The cost of a lens increases with its diameter because of the complex grinding processes. In industrial TV applications, another limiting factor to the use of large diameter lenses is the small size of the target area.

The formula indicates: **the smaller the f number the more sensitive the lens.** Consequently, more light is delivered to the vidicon target using a lens with a small f number. This is a very important consideration in obtaining a picture of good contrast and low noise content. A small-f lens is mandatory at low ambient light levels.

The formula also indicates that the shorter the focal length of a lens of a given diameter, the higher the speed and the smaller the f number. In terms of lenses of approximately the same diameter, the longer-focal-length types generally have the higher f number. In other words, under difficult lighting conditions, it is best to choose a lens with a small f number and a short focal length. Remember that the short focal length indicates that for a given field of view the camera can be positioned nearer to the area to be televised.

The usual lens mounting arrangement for an ITV camera includes an iris adjustment ring which is calibrated in f numbers and a focusing ring which is used to position the lens properly with respect to the target area to bring the given televised area into correct focus. The adjustable iris is in the form of a diaphragm which can be used to vary the lens' effective diameter. The actual diameter of the lens is the value obtained with the iris wide open. For a very bright scene the iris can be closed down, reducing the effective lens diameter. As a result, the sensitivity of the lens is reduced but there is a greater depth of field.

The final lens characteristic of importance is depth of field. The depth

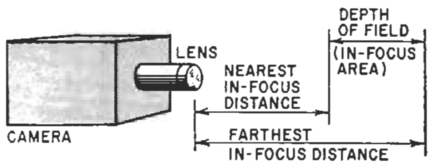


Fig. 3—Depth of field is in-focus area covered by ITV camera.

of field, as shown in Fig. 3, is the distance from the nearest point of sharp focus to the farthest point of sharp focus. A lens system must be chosen that permits the nearest significant object in the televised area to be in focus as well as the farthest object.

A number of procedures can be followed to increase the depth of field. The depth of field is greater with a shorter focal length lens. It is greater with a slower lens (larger f number), and a greater separation between the object and the camera for a lens of a given f number. If a lens has an iris adjustment, depth of field can be increased by stepping down the iris to a smaller aperture. An iris is stepped down by adjusting it to a higher f number (smaller opening). Of course, this means that less light is admitted and is certainly not advisable at low ambient light levels. However, with abundant light available, the depth of field and picture quality can be improved by stepping down the iris setting.

It is always advisable to limit illumination to the vidicon camera tube to 200 foot-candles. In this way, the camera tube can be operated under its most favorable conditions. When light levels exceed 200 foot-candles, the lens system can be adjusted to reduce the light and increase the depth of field and magnification of the area observed. At low light levels, compromise techniques must be employed. Generally, the most sensitive lens arrangement must be employed—a short-focal-length lens of high speed, lens iris wide open, and camera positioned as close to the televised area as possible to include the important information to be conveyed in focus.

Lighting considerations

In most ITV installations there is no objection to supplemental lighting when needed. Properly positioned lights above and to the side of the camera can do much to give a picture with superior contrast and improved definition. Many TV cameras include special wide-band video facilities. With abundant light available, the video amplifier can be switched to a wide-band position. This increases the system's frequency response and produces a picture with better resolution.

When the video amplifier system is operated in the wide-band position, the system's overall gain is reduced and, in some cases, the noise content is increased. As a result, abundant lighting must be available to generate a video signal capable of overriding the circuit noises and strong enough that, with the gain available, a picture of full contrast can be developed on the screen of the monitor. At low ambient light levels narrow-band operation of the video amplifier is preferable. The video gain is greater and the noise content lower. Hence, there is maximum amplification of whatever video signal level is made available at the camera tube's output.

Light levels are generally measured in foot-candles. For best results, the vidicon camera tube requires some 30 to 200 foot-candles. Below 15 to 20 foot-candles the picture develops some grayness and is not as clear and sharp. Very bright objects in the scene have a tendency to stick or smear. Lighting in excess of 200 foot-candles makes no noticable improvement and, if this much light is available, the lens system can be stopped down for additional optical advantages.

Light meters are available to measure the incident light directly in foot-candles. Such meters are commonly employed by amateur and professional photographers. The best method to measure light levels is to position the light meter near the subject to be viewed and point it in the direction of the camera location.

Always keep in mind, to avoid damaging the target surface, not to point the camera directly either at the sun or any intense source of light. Try to arrange the installation so the bulk of the available lighting is above or to the side of the camera mounting position. Either fluorescent or incandescent lighting can be employed. Sometimes the combination of both aided by daylight from a window, determined by the color range of the material to be televised, renders the best picture. In other cases one may be better than the other. In the transmission of objects with color ranges largely in the red region, incandescent lighting will often provide the best operating condition in terms of picture and necessary lighting power. When the objects range over the entire color spectrum or are concentrated in the blue region, fluorescent lighting is preferable.

In general, the background should never be as bright as the main object or objects to be viewed. Normally, white and glossy backgrounds should be avoided.

In most industrial TV installations the area to be covered is small (generally no more than 20 feet in diameter and in most cases considerably less). As a result, simple reflector or projector type lamps can be easily installed either individually or in banks. Standard fluorescent lights and fixtures can also be employed conveniently.

Many reflector and projector lamps have front surfaces formed into a lens so that specific spot or flood patterns can be obtained. It is surprising how many foot-candles of light can be added using very simple and inexpensive lamp installations.

The chart shows the number of foot-candles that can be contributed by rather low-wattage lighting. The chart indicates available foot-candles as a function of distance between light and objects in terms of lamp wattage and type.

When very small areas are to be televised in data pickup service, miniature fluorescent lamps are often advantageous because of their cooler light. Daylight fluorescents generally render the best reproduction when a wide range of colors are represented in the information to be televised.

The installer of an industrial television system must have some knowledge of lenses and lighting. With this knowledge he can get a high-quality picture under favorable lighting conditions and make certain that practical and usable pictures can be obtained under more adverse conditions of television pick-up. END

LAMPS VS LIGHT OUTPUT

	Distance in Feet				
Reflector Lamp	5	10	15	20	30
75-watt spot	60–80 foot-candles 1-ft spot	15–20 foot-candles 2-ft spot			
75-watt flood	12–20 foot-candles 2-ft spot				
150-watt spot	200–275 foot-candles 1-ft spot	50–70 foot-candles 2-ft spot	25–35 foot-candles 3-ft spot	15–20 foot-candles 4-ft spot	
150-watt flood	44–50 foot-candles 2-ft spot				
300-watt spot	500–660 foot-candles 1-ft spot	120–160 foot-candles 2-ft spot	40–50 foot-candles 3-ft spot	35–40 foot-candles 4-ft spot	15–20 foot-candles 6-ft spot
300-watt flood	80–110 foot-candles 2-ft spot	22–29 foot-candles 5-ft spot			