A HISTORICAL REVIEW OF THE DEVELOPMENT OF AN EXISTING-LIGHT SYSTEM OF MOTION-PICTURE PHOTOGRAPHY

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During the early 1960's, Kodak introduced a new film for amateur movie photography - Kodachrome II, replacing Kodachrome I. The new film had a daylight ASA exposure index of 25; a front-lit summertime scene in bright sunshine was exposed at an aperture of f/11-f/16 with a normal shutter speed of about 1/35 second at the prevailing cine-8 rate of 16 frames per second.

With the subsequent introduction of Kodachrome-X film in 35mm and 126 Instamatic sizes, it seemed desirable to spool this higher-speed film in cine-8 size and, thus, provide amateur movie makers with the capability for extended-range photography. The idea was impractical, however, because that 1962-63 generation of cameras, with f/16 the common minimum aperture, was already at its limit with Kodachrome II, and could not handle a faster film in bright outdoor daylight.

All this seemed to impose a restrictive ceiling of EI 25 for film speed in amateur motion-picture systems. Realizing that future film developments would always include steps toward higher-speed emulsions, we set out to find ways to "use up" speed in cameras, so that faster films could be accommodated.

Correct photographic exposure depends on shutter speed, lens aperture, and film speed; so for any given film we are left with two exposure controls, aperture and shutter speed. In the motion-picture systems we were concerned with, smaller apertures than f/16 were unacceptable because of the severe degradation of image quality from diffraction at very small apertures. Neutral density filters could allow some exposure control, but in general they also tend to degrade the image, and are a nuisance to use. That left us with only shutter speed as a means of altering the photographic exposure.

The shutter in a motion picture camera is a rotating disk consisting of a solid, dark sector for covering the film while it is being advanced from one frame to the next, and an open sector, which allows the exposing light from the lens to reach the film, (figure 1). The exposure time (Shutter speed) at a given frame rate is determined by the size of the open sector. For example, at 16 frames per second, each frame has a "lifetime" of 1/16 second, so that a shutter half dark and half open (180° of a circle each), would produce an exposure time of 1/2 of 1/16 or 1/32 second. A shutter with an open sector of 90° would expose the film for only 1/64 second, and so on, (figure 2).

Most cine-8 cameras had shutters with an open sector of about 165°, giving exposures of about 1/35 second per frame. In order to shorten that time we investigated narrow-angle shutters, realizing that the animation, or jitter, or stroboscopic, effect could be a problem. It was. We accomplished the goal of being able to expose Kodachrome X in bright sunlight, but the jitter in moving objects was intolerable. In fact, we were surprised to find that even with the normal 165° shutter we were dissatisfied with the jittery appearance of objects in motion. It looked as though an even better system of smoother motion lay beyond 165°, in the realm of wider-open shutters. For all intents and purposes that was the end of our search for a way to lose speed in a movie camera. Critical observation of the results of experiments with narrow-angle shutters pointed us in exactly the opposite direction, the one which finally led to the Kodak XL movie system, in which we gain speed in the movie camera.

The desire to obtain longer exposure times per frame imposes a restrictive condition on the motion-picture system. Each degree of shutter sector opened up for exposure means a degree less of dark or pulldown time for advancing the film to the next frame. It becomes necessary then, to use a faster pulldown mechanism in the camera. The solution to the problem turned out to be much simpler than first expected.

For many years, motion picture projectors have used a three-bladed shutter rotating in the light beam to increase the flicker frequency to a point where it was not generally visible to the eye. Each blade covered a 60° sector of a circular disk. All three blades chopped the light beam during projection of each frame, but the film pulldown occurred behind only one of the sectors, being accomplished in only 60° of shutter rotation, (figure 3). This was the type of rapid pulldown we needed.

Fortunately for us, cameras had been marketed in about 1960 that could also be used as projectors. These were the Wittnauer Cine-Twin series; they possessed one remarkable attribute - they incorporated a rapid pulldown mechanism for advancing film in only 60° of shutter rotation. These cameras used a double shutter, (figure 4). The outer portion contained two equal sectors of 180° each, one dark and one open, usable in the camera mode. The inner portion contained six 60° sectors, three dark and three open; these were brought into position in the projection mode when two reel-holder arms inside the body were raised upward. The 60° pulldown mechanism operated in both modes, being unfortunately wasted in the picture-taking phase of camera use. It was a simple matter for us to cut away all the excess metal from a disk, retaining a single 60° blanking or dark sector for film pulldown, leaving us the remaining 300° open sector for exposure time, (figure 5).

In contrast to 1/35 second per frame we now had a time of 1/19 second, almost a full stop more exposure capability, without a new wider-aperture lens or a faster film.

All this sounds great, but does it work? One of the first questions which arises refers to the effect of the slower shutter on the motion-picture image. Is it less sharp, more blurred? For objects in motion the answer is yes, but a qualified yes. The image of each frame is slightly less sharp, but the over-all effect is that objects in motion now have a smoother, less jittery appearance.

The explanation is quite simple - imagine an object moving laterally across the field of view of a motion picture. A short-exposure, narrow-angle shutter produces a sharp, crisp image of the object, which then continues to move during the relatively long dark time until the next frame, when its sharp image again appears, but displaced to such a degree that it seems to have "jumped" laterally, giving rise to the jerky, jittery impression of its motion. A longer-exposure, wider-angle shutter produces a less sharp image of the object in each frame, but since the dark time between frames is now fairly short, the lateral displacement of the object is much less, so that it seems to have flowed more smoothly in its motion.

For most movie photography the differences in motion recording between a 165° shutter and one of 300° are difficult to distinguish, and many observers, even when instructed to look for obvious clues, were unable to see differences in side-by-side scene comparisons. We had achieved a practical workable wider-open shutter that had no detrimental effect on projected motion pictures.

Having "found" nearly a full stop in camera speed with the new shutter, we wondered what else could be done to extend the range of movie-making capability. The fastest lens available at that time was a Switar f/0.9 designed for the Bolex camera. We tried one, and were pleased with the additional exposure range that the lens provided. We also investigated a variety of films, from KODACHROME-II at EI 25, and KODACHROME-X at EI 64, to KODAK high speed EKTACHROME films at EI 125 and EI 160.

During the course of shooting many movies on these films under a great variety of conditions, we discovered that there was a cutoff point for exposure modulation, a point beyond which pictures looked peculiar because they actually appeared brighter on the screen than the original scene did when it was photographed. Much of our work from then on was devoted to finding where that cutoff point lay, and how best to describe and achieve it.

In photography we record scenes having greatly different brightness levels by modulating the exposure to a "normal" condition which places the highlights, middle tones, and shadows on the appropriate portions of an H and D curve. It will be easier to describe the exposure cutoff point referred to earlier if we define a normal exposure slightly differently. Consider that a "normal exposure" is one that produces on our screen a projected image that looks like the original scene did at the instant it was photographed. Then, let's consider various lighting levels and how they affect normal exposure.

A brightly sunlighted scene requires a small aperture, a short shutter time, or some combination that achieves the desired exposure as indicated by a metering device. As the light level drops lower and lower, we can continue to give a series of normal exposures, using appropriate combinations of shutter and lens aperture, according to our meter indications. When the pictures are projected, all these normal exposures will appear to have the same brightness. However, if we continue to increase exposure according to our meter, no matter how dim the illumination becomes, we will eventually obtain pictures that appear brighter than the original scenes. Somewhere in the series a transition will occur, from pictures that appear "normal" to those that appear "over bright", (figure 6). A long series of practical picture tests has shown that this transition or cutoff point occurs at a scene brightness in the range of about 6 foot-candles. If a system operating "wide open" gives a metered normal exposure at that illumination level, that same maximum exposure can be used

3½ to 7

7

to record many dimmer scenes below the 6 foot-candle range. What happens is that dimly lighted scenes are reproduced as correspondingly darker pictures on the screen, looking like reasonable reproductions of the original scenes. In looking for a "handle" - a simple way of referring to that last normal exposure condition in the 6 foot-candle range, we almost jokingly coined the word TEMS, referring to the Terminal Exposure Modulated Scene. The name stuck, and has been in literal use among existing-light research workers for the past half-dozen years.

The final combination of system components that allowed us to reach the TEMS exposure was a camera operating at 16 frames per second with a 300° shutter, producing a 1/19 second exposure, through an f/0.9 lens onto Kodachrome-X film at EI 64. While each of these components can be varied, the system requirements must be capable of producing the required maximum exposure. One cannot simply approach the TEMS condition, it must be met; otherwise, everything from that level on down will be unacceptably underexposed.

A great deal of discussion has ensued among workers interested in scientific accuracy as to just what the absolute value of TEMS is. Because of differences in scene characteristics - lighting contrast, for example - it is impossible to name an absolute value. That question is really academic anyway, because the greatest practical benefits of our existing-light system are derived from its ability to photograph scenes in the range of brightnesses from about 200 foot-candles on down. Here are a few typical illumination levels in that range:

150 foot-candles - spotlighted stage, sport, and ice shows, college basketball, TV screens.
100 foot-candles - bright offices and stores, pro football, bowling lanes.
50 foot-candles - daylight home interiors, bank lobbies, schoolrooms, scholastic sports, theater stages.
20 foot-candles - gymnasiums, swimming pools, airline terminals.
10 foot-candles - meeting rooms, speakers' podium.
5 foot-candles - social assemblies, christmas lighting, hospital nursery, home interiors at night.

You will, of course, recognize that many of these represent areas of highly desirable picture situations, nearly all of which have up to now been denied to the amateur photographer. Except for bright exterior daylight, most of the world in which we live falls into the photographic range opened up by the Kodak XL movie system.

The old system, using Kodachrome II, had an exposure capability of about 6 stops (1.8 log E). The new system adds at least 4 1/3 stops more, for a total system capability of 10 1/3 stops (3.1 log E), (figure 7).

The final design of the Kodak XL super 8 movie cameras has incorporated a shutter with an open sector of 230°, operating at 18 frames per second to produce an exposure time of 1/28 second. The lens has a maximum aperture of f/1.2. These two features in combination with a new film, Kodak Ektachrome 160 provide a system that is capable of photographing the complete brightness range from full sunlight to the very dim conditions around which most of this discussion has centered. The system accommodates high-brightness scenes by means of a new type of neutral density filter built into the camera.

The final success of any idea depends upon its reduction to practice, in a form that can bring to the final consumer the results that we set out to achieve. That reduction to practice of the concepts described in this review was accomplished by the efforts of a great many people - research and development engineers and technicians who built a new film and process system, and the camera designers and engineers who came up with a piece of equipment that is novel in many of its aspects. We would like to credit each of them personally, but since we can't do that here, let's just say that based on picture results from the Kodak XL movie system we feel that they did a fine job.

(A selection of cine-8 movie scenes was shown, consisting primarily of footage shot during early explorations into the existing-light system. Running time approximately 8 minutes.)

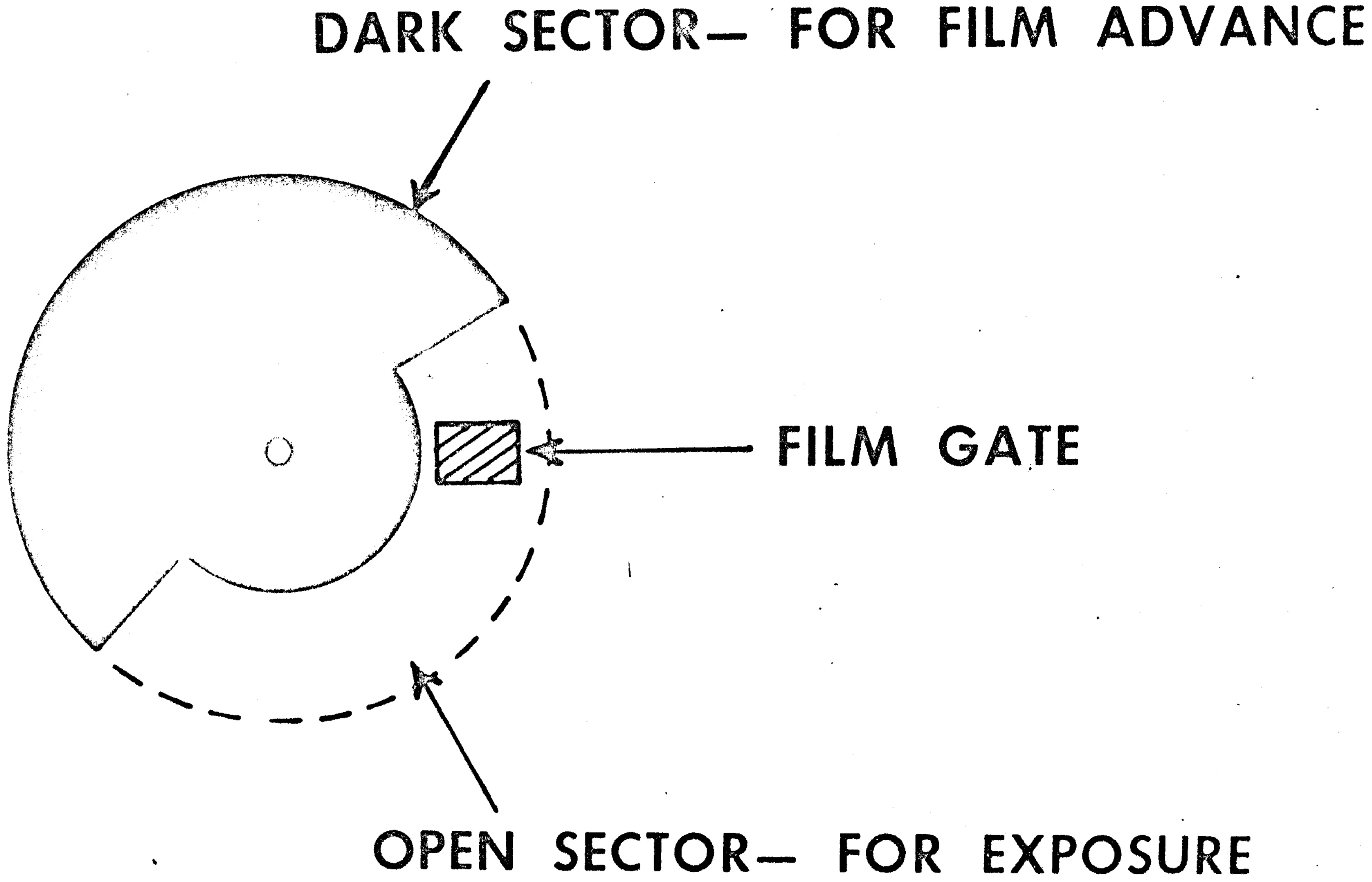

DARK SECTOR— FOR FILM ADVANCE
FILM GATE
OPEN SECTOR— FOR EXPOSURE

Figure 1

AT 16 FRAMES PER SECOND:

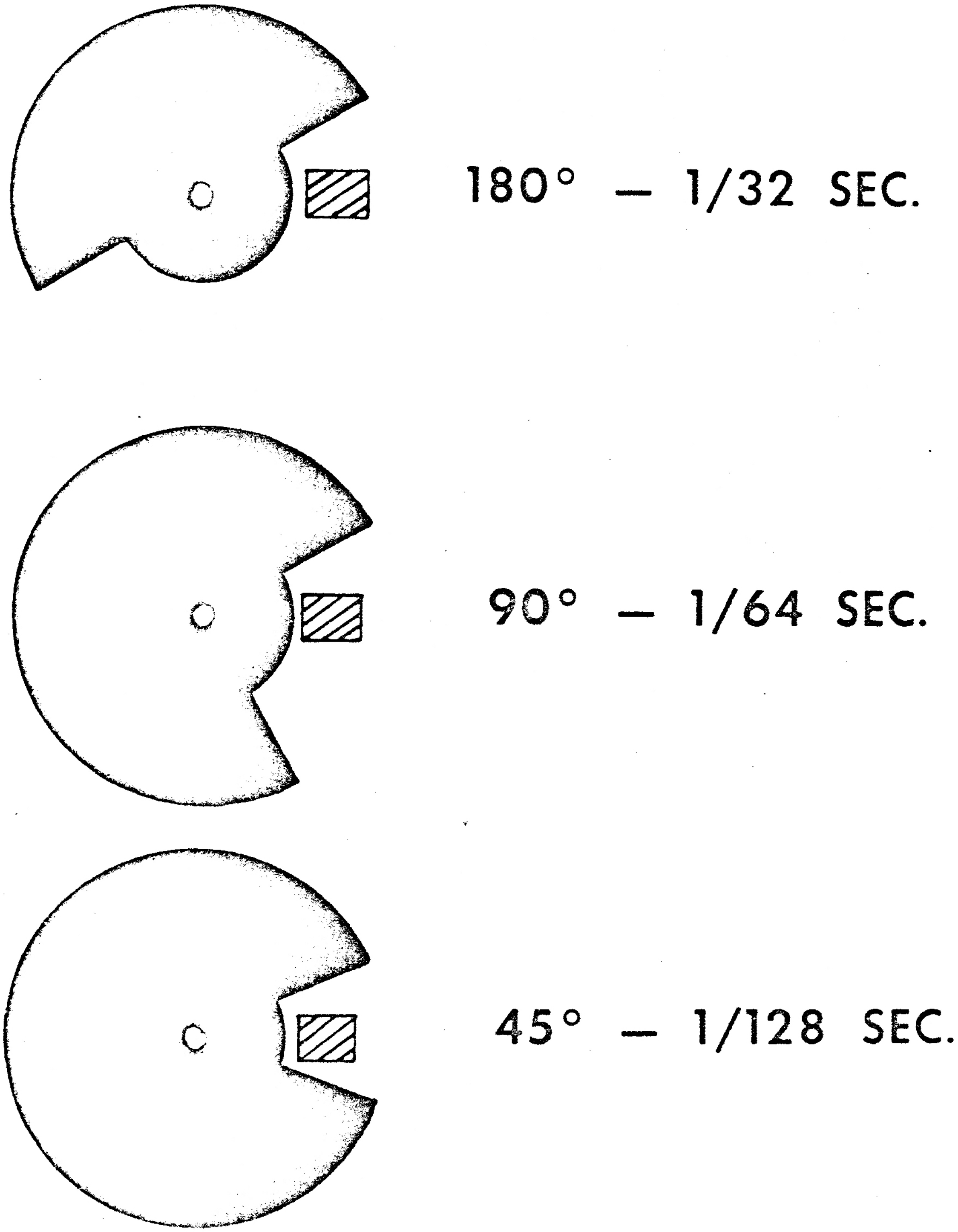
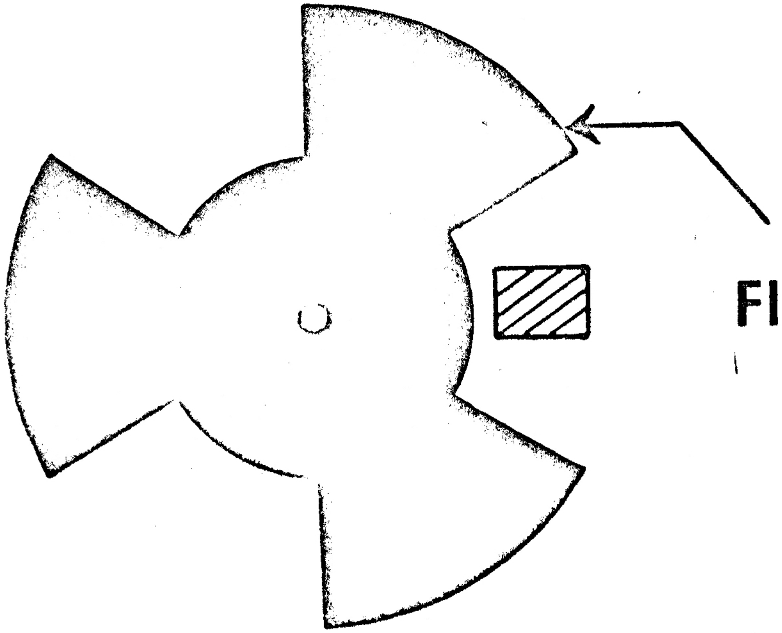


Figure 2

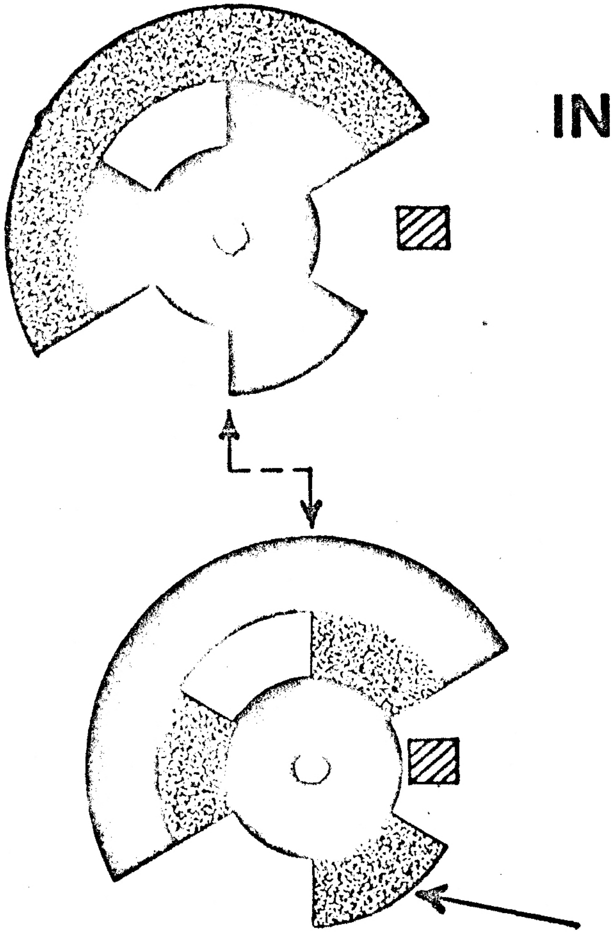
PROJECTOR SHUTTER



FILM PULLDOWN OCCURS
BEHIND ONLY ONE
DARK SECTOR

Figure 3

WITTNAUER 'CINE-TWIN' SHUTTER

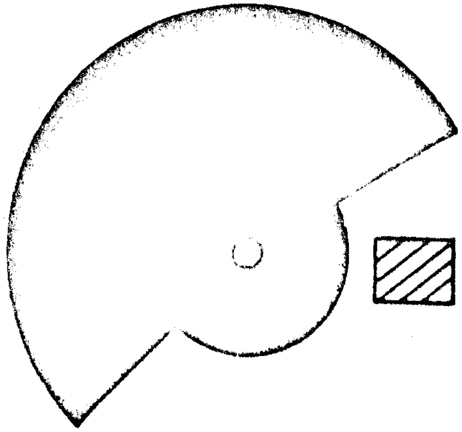


IN CAMERA MODE

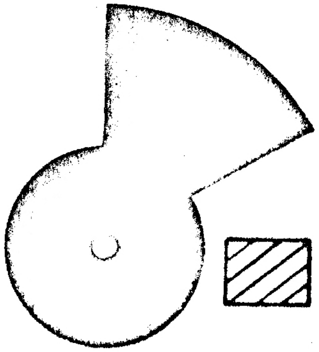
IN PROJECTOR MODE

FILM PULLDOWN OCCURS
BEHIND ONE 60° DARK SECTOR

Figure 4



165° SHUTTER — 1/35 SEC.

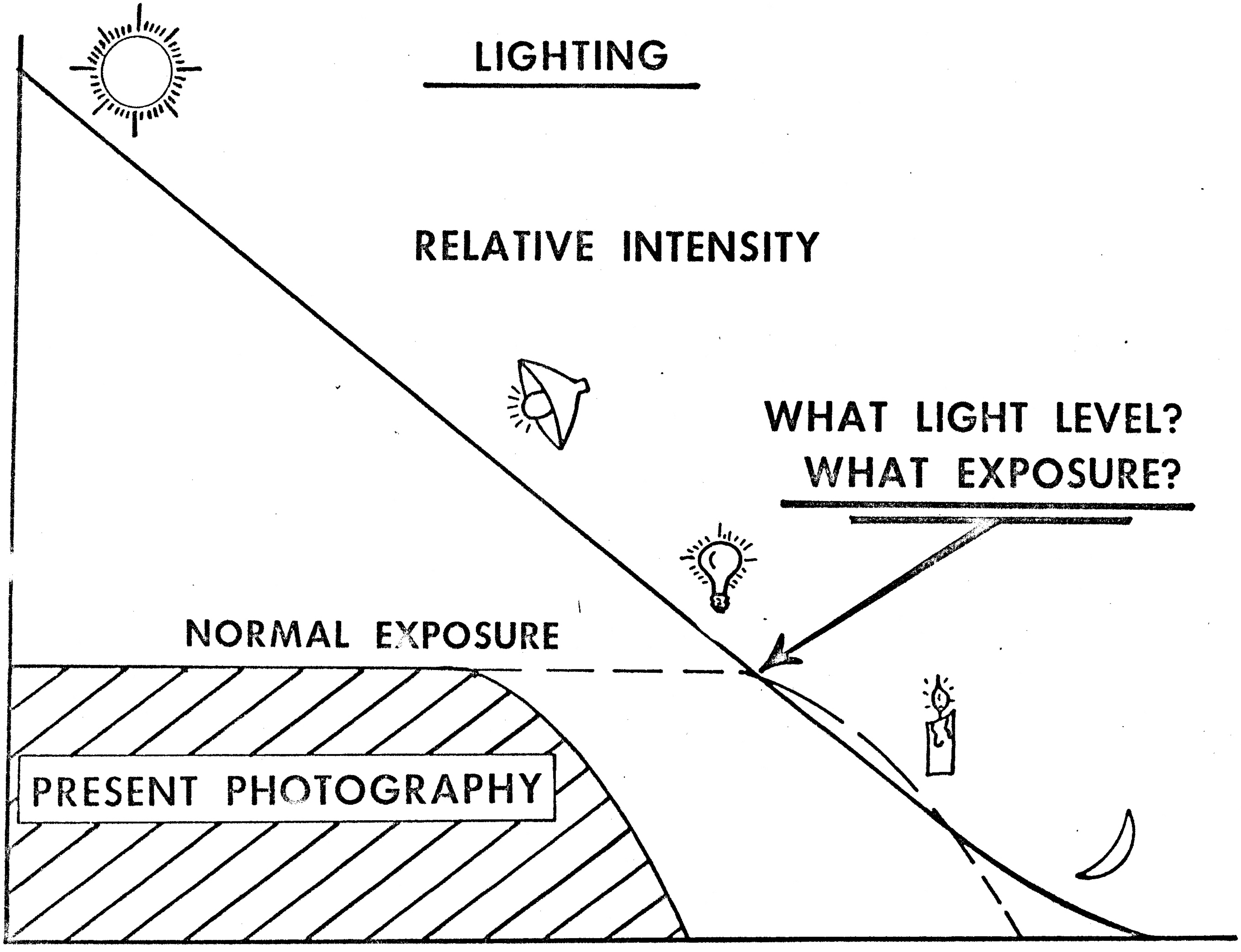


300° SHUTTER — 1/19 SEC.

+ .26 LOG E INCREASE IN EXPOSURE

Figure 5

LIGHTING


RELATIVE INTENSITY
WHAT LIGHT LEVEL?
WHAT EXPOSURE?
NORMAL EXPOSURE
PRESENT PHOTOGRAPHY

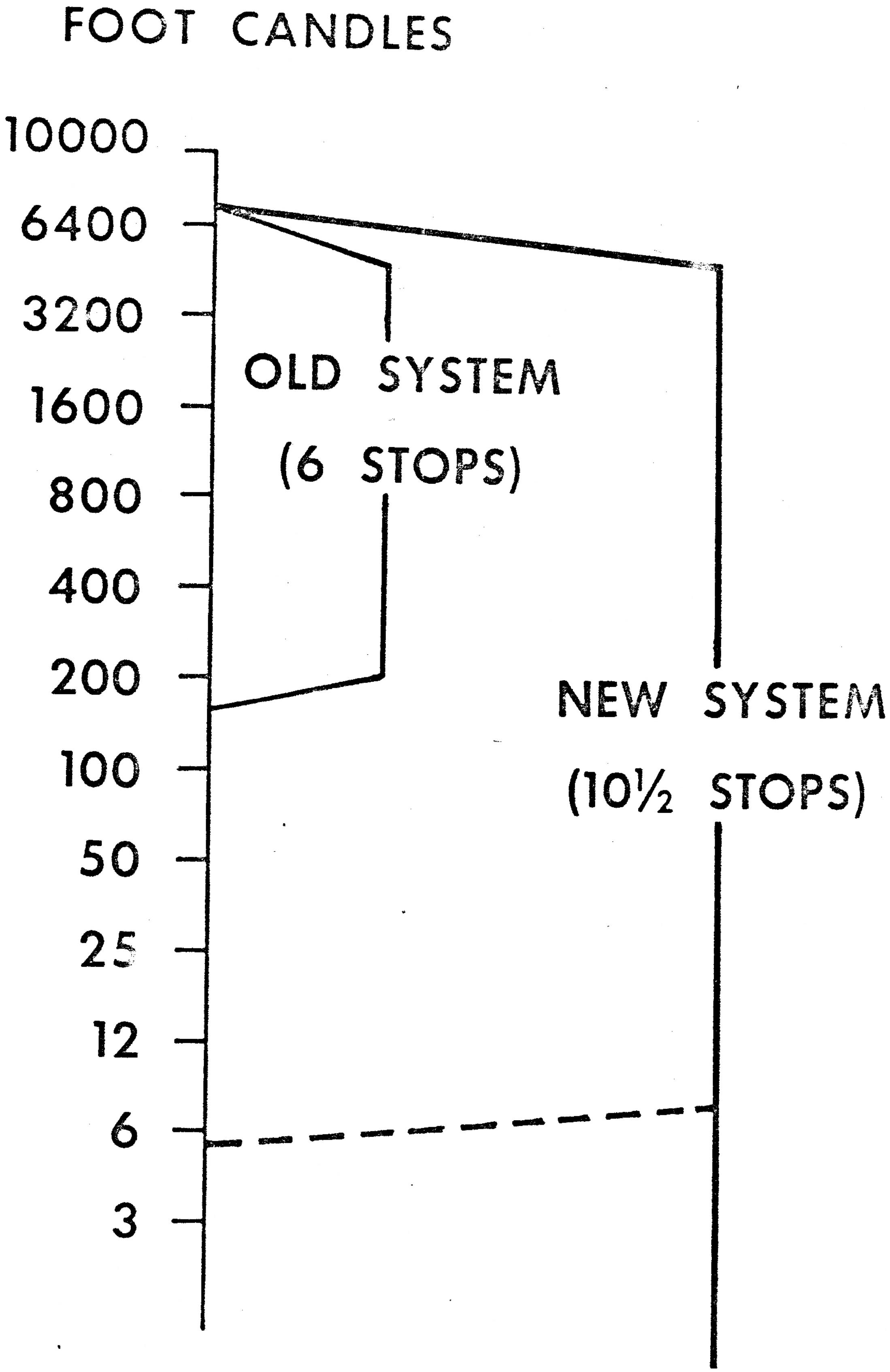

FOOT CANDLES
10000
6400
3200
1600
800
400
200
100
50
25
12
6
3
OLD SYSTEM
(6 STOPS)
NEW SYSTEM
(10½ STOPS)

Figure 7