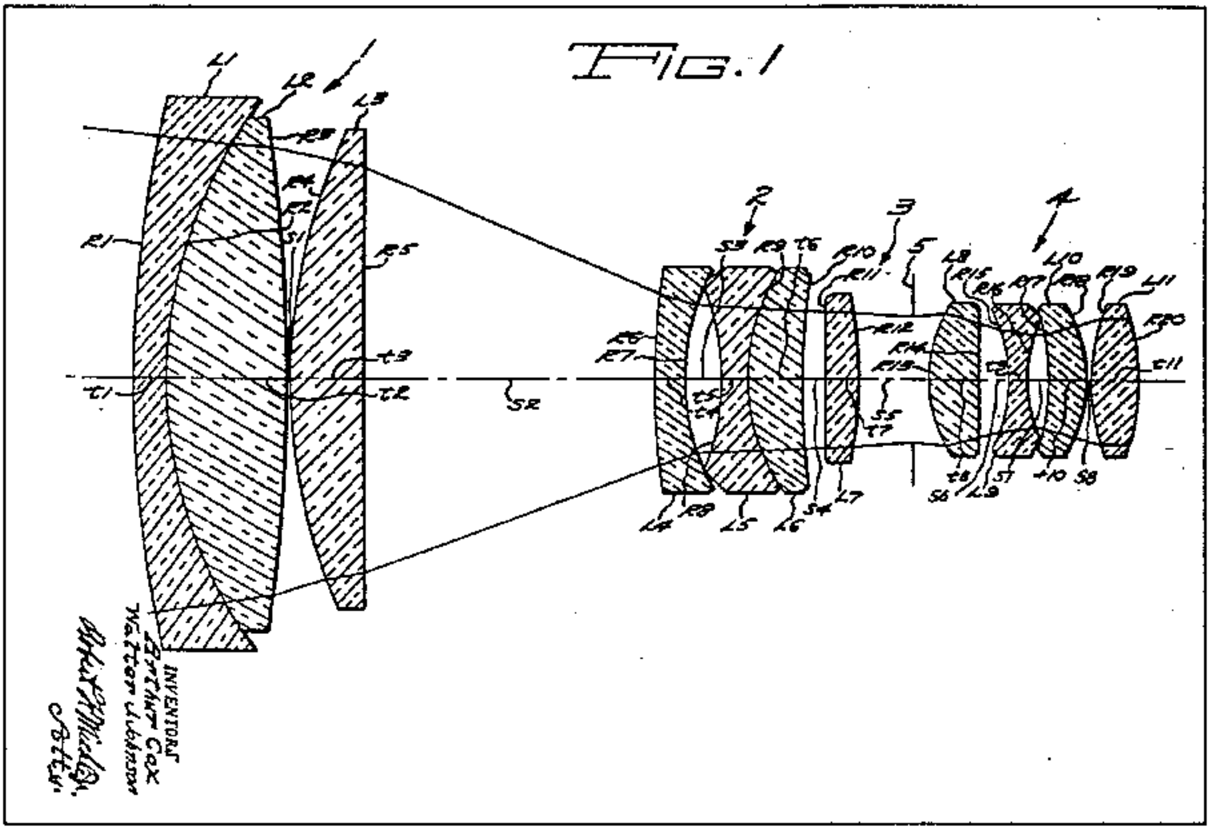
Part 2

Optical/Image Characteristics

Varamat Zoom Lens:



The 3:1 zoom lens of the 414 camera series had eleven elements and reported to be of excellent quality. I had the good fortune to review the Varamat lens characteristics at a lunch meeting with Dr. Arthur Cox, the former President of Bell & Howell Optical Division.

That good fortune was expanded by the presence of Frank Mellberg who was the designer of the zoom mechanism.

Both related to me some of the challenges and "war stories" of maintaining their industry quality leadership position. That quality position was confirmed in correspondence from the former Director of Engineering of the Optical Division, Mr. Rudolf Hartmann. He related: "In another laboratory study (B&H Project Report "Resolving Power of 8mm camera lenses", 17 January, 1961), we compared 31 8mm camera lenses and found that the static photographic performance on Kodak Plus-X Pan film of the 9-27mm f/1.8 Varamat, used on the 414 camera, was superior to competitive and older B&H design lenses: the Varamat had an unusually flat resolution curve across its picture format (9 field position, 3 focal lengths, full aperture), yielding more than 60 lp/mm (line pairs per millimeter) resolution. Visual (air-image) resolution was 225 l/mm min. at any test position."

Any attempt on my part to provide details on the lens or the zoom mechanism would be redundant. Dr. Cox and Mr. Mellberg confirmed that their patents, Cox #3074317 and Mellberg #3059533, are directly applicable to the 414 camera series. Both are appended to this report for reference and study.

The size of the images produced by the Zapruder camera met all the minimum area requirements of the then existing standards. However, because the camera intermittent design provided for the camera claw or pawl to enter adjacent to the image aperture at perforation "0" and pull down to perforation "+1" (described in Part I, see Figure 4-9), the cutout area required for the claw allowed the lens to expose scene information into the area between the perforations. It is this image data, outside the typical camera image area, that has been the cause of concern, misunderstanding, and speculation of contributing to the so-called "image anomalies".

"Windows" of the Lens:

We have already defined that the 414 Varamat lens was one of superior quality. We have also noted that the optical consideration of importance is the image extending beyond the typical into the area between the perforations.

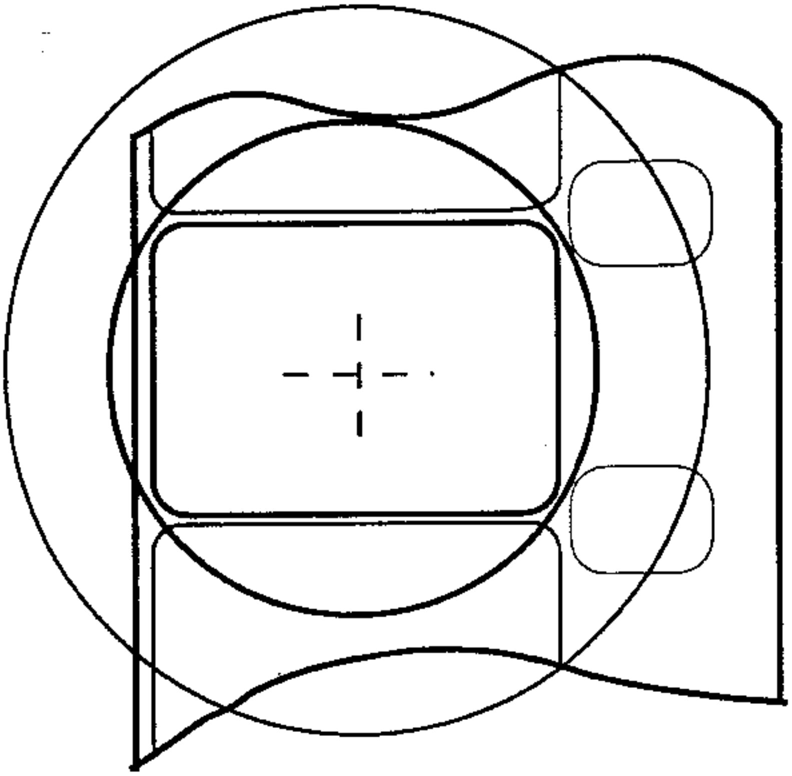
Lenses are commonly round and the required picture area is rectangular. To meet minimum requirements, the *exit window* of the lens must be at least equivalent to the diagonal of the picture area. Anything greater is of no consequence and measurements are made only to ensure there is no vignetting or corner fall-off.

In simplest terms the *entrance window* of a lens defines the area of the object we are looking at; and the image in the lenses following it is called the *exit window*, since this defines the area of the image seen.

With the Varamat lens, we have a multielement 3:1 zoom lens – the *entrance window* changes and the *exit window* maintains at least a

Varamat Lens "Exit Window"

Conceptual Presentation



The two circles represent "Exit Windows" of the Varamat lens at the two extremes of focal length. The inner circle is the bright or effective illumination for Wide Angle and the larger circle represents the effective illumination for Telephoto.
Note the significant difference in penetration into the area between the perforations. Also note the image light penetration above and below the perforations. (See text)

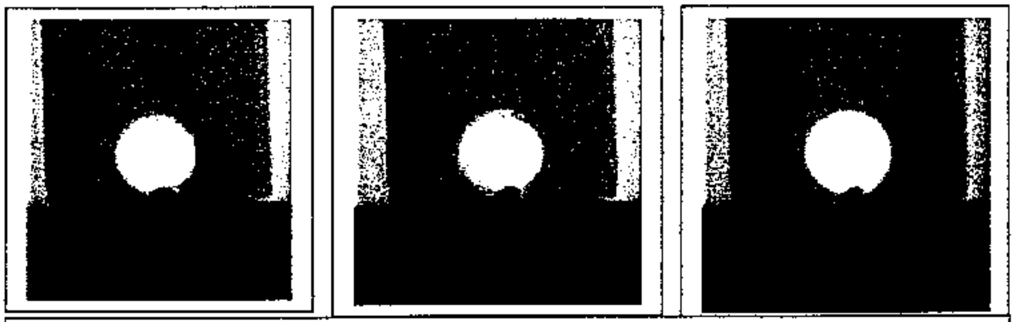
Figure 4-15

minimum size equivalent to the diagonal of the image area. The maximum required diagonal is determined by the picture height which cannot exceed one perforation pitch of the film, 0.150 inch (one picture height per pitch length), and is 0.250 inch. A conceptual visualization of the *exit windows* seen with a B&H 414 camera is shown as drawing Figure 4-15.

To determine if the *exit window* size varied, the aperture plate was removed and a light was imaged through the lens onto frosted acetate to observe (as close as possible to the film plane) any change in *exit window* size with changes in focal length. Be aware that the evaluation was not done on an optical bench and was intended to be conceptual to gain an understanding of a significant lens parameter.

We observed that there were changes. Although the full *exit window* remained almost the same, the effective illumination area changed by the presence of dark peripheral rings at the wide angle through normal lens setting. These dark rings began at a diameter slightly greater than the image area diagonal.

Three positions were measured with the shutter open with uniform diffused illumination. Hand held measurements showed an *exit window* diameter of, 0.026 in. Wide Angle; 0.28 in. Normal; and 0.34 in. to 0.36 in. Telephoto. The distance from the horizontal center of the image to the outside edge of the perforation is 0.172 inch meaning that an *exit window* diameter of 0.34 would provide image-forming light to the outside edge of the perforation. The images formed between the perforations are multi-dependent on lighting, focal length selected, aperture-opening, etc. The significance of these values will be reviewed in Part 3 - *Recognized Image Anomalies.* (See Figures 4-16, 4-17 and 4-18.)



Figures 4-16,17 & 18 Exit Window Photos of Varamat lens. Left is Wide Angle, Center is Normal and Right is Telephoto. Note diameter relative to the claw and The difference in the characteristics of the edge for Wide Angle and Normal.

Electric Eye and Iris Diaphragm:

My good fortune in obtaining support for describing many of the features of the 414 camera continues in giving the reader design and engineering details on the automatic exposure system. An article, *A Direct Drive Automatic Iris Control* by LaRue, Bagby, Bushman, Freeland and MacMillin was published in the September 1958 issue of the SMPTE Journal and is appended. Although the camera described preceded the 414 camera series, Mr. MacMillin has confirmed that the engineering described is directly applicable to the 414 camera series. The system was rugged and long-lived. All of my old test cameras give good exposure results. For perspective here, I have extracted a few highlights from the article that will aid in understanding the accompanying photos on components of the system.

The exposure sensing is achieved by feedback from two photo-voltaic (Se) cells, one sensing overall scene illumination and the other sensing paraxial luminance for backlight compensation. (Hence the "D" in 414PD relates to dual electric eye.)

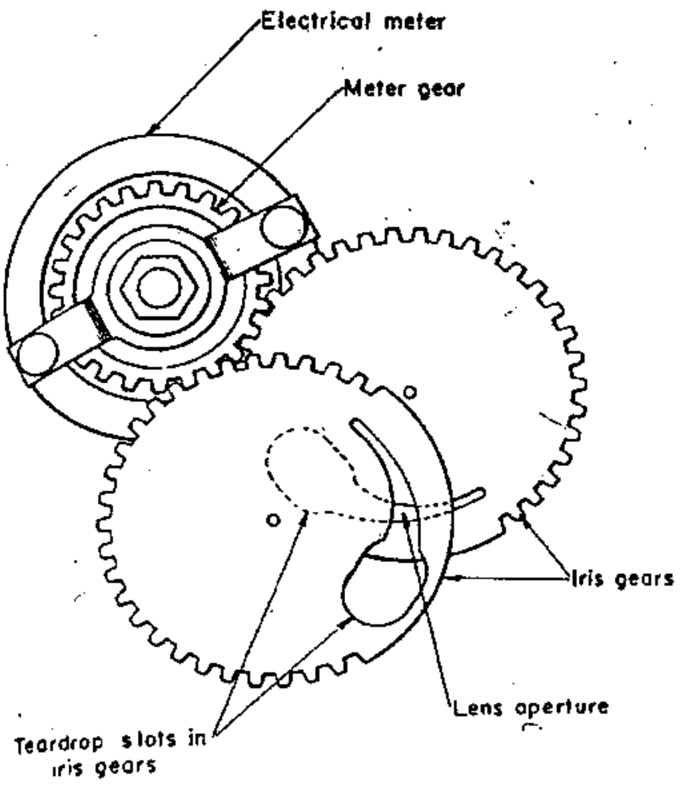


Figure 4-19 Depiction of Iris Gears in 414 Camera

The iris diaphragm in the 414 camera series uses two overlapping disks each of which has a teardrop shaped angular slot. The intersection of the two slots forms the variable aperture. See Figure 4-19. Gear teeth are formed on the periphery of the disks that engage a gear mounted on the meter coil. The rotational inertia of the two iris discs has been arranged to oppose that of the meter armature with the desirable result that the effect of externally applied rotational movement can be eliminated.[8]

Because a single frame release is provided on the camera, a manual control F1.9 to F22 can override the automatic feature for special effects, strong backlighting or abnormal contrast. The meter can be set to automatic for film speeds of 10, 16, 25, and 40 ASA. The response speed of the electric eye/iris is six lens stops per second due to the low rotational inertia of the moving parts.

A grid or baffle establishes the acceptance angle for exposure determination within which direct rays are transmitted to the photocell. As mentioned, a second photovoltaic (Se) cell that senses direct sunlight and is linked to the main photocell is such a way as to cause the iris to open a given amount - i.e. backlight compensation.[9]

Unusual Iris Shapes:

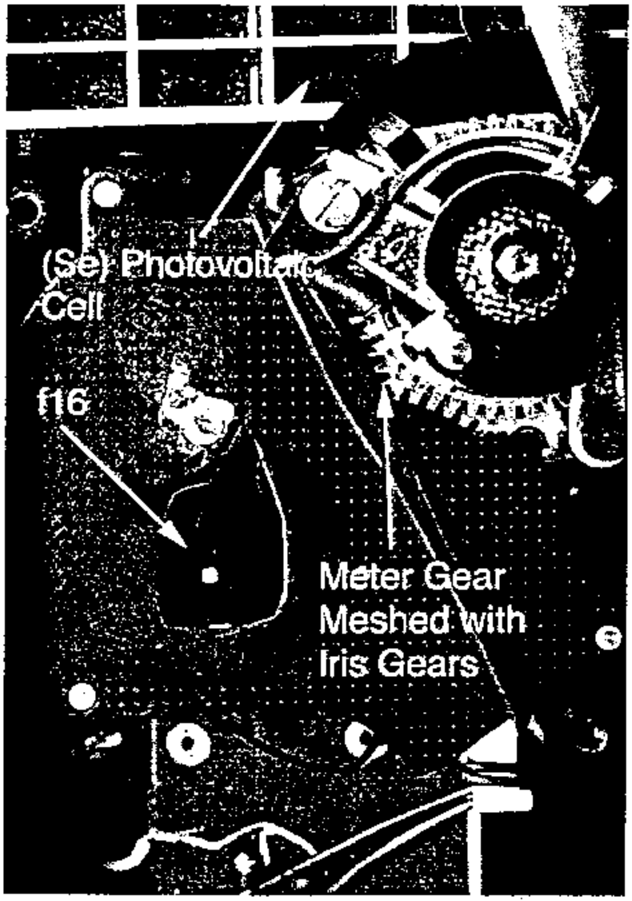


Figure 4-20 Iris Gears

Because the cut of slots in the two iris blades are not linear (as shown), unusual patterns can be formed as seen from the series of photographs of aperture openings. (Figures 4-20 through 4-22). The subject of iris patterns and its effect on the resulting image is well documented in the literature on optical physics. Its significance here is the question of whether or not the possible unusual patterns yielded image artifacts. The answer is yes and no!

If the subject is <u>not</u> in focus inversion, multiple images, etc. can and do occur. However, if the image is

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[8] Note Mr. Hartmann in his correspondence (appended) refers to one blade as stationary, however my disassembled camera construction matches that described in the referenced LaRue et al article where both iris blades rotate.

[9] For a discussion on backlighting problems, see MacMillin, David, *Improved Automatic Exposure Control*, JSMPTE, Vol. 71, July 1962, pp. 510-511.

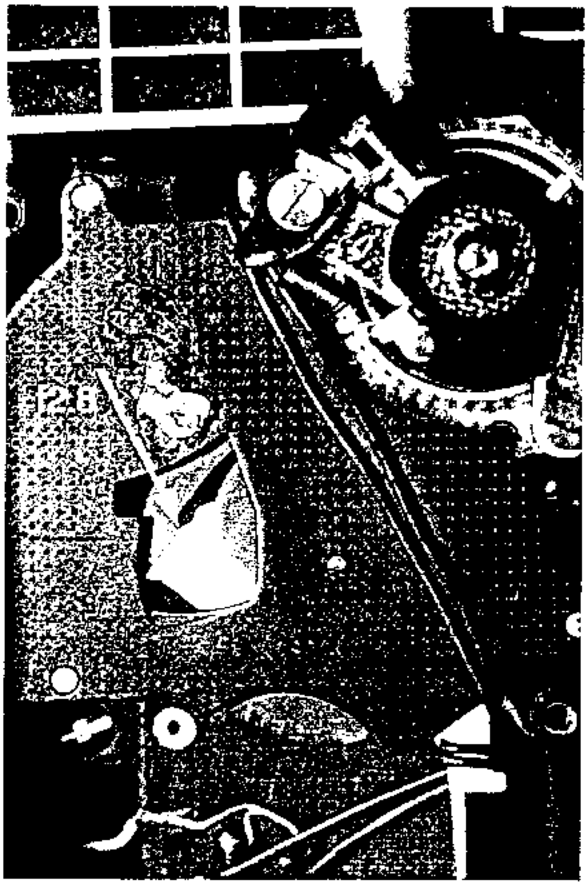


Figure 4-21 Slightly Unusual Iris Shape

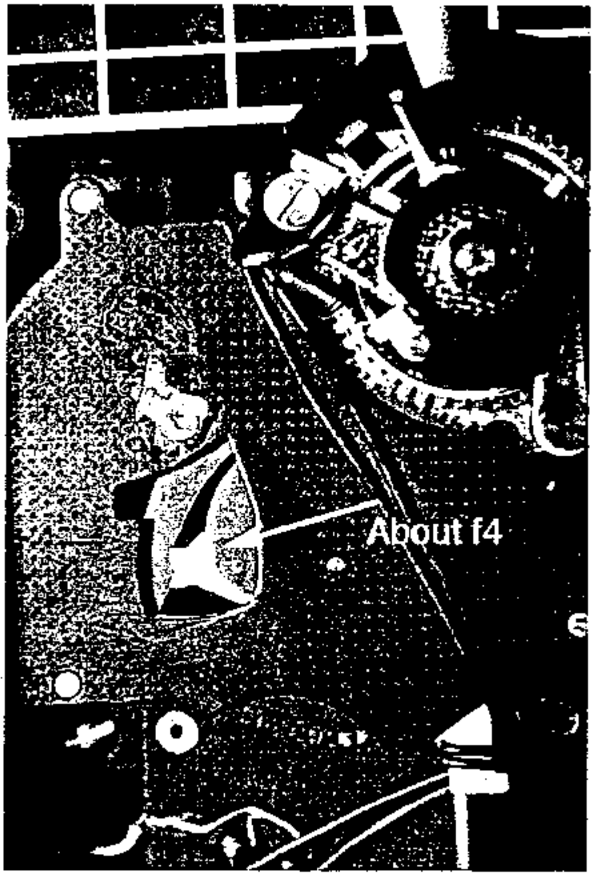


Figure 4-22 Unusual Iris Shape

focused properly, the iris pattern makes no difference. Bell & Howell tested for this effect as reported by Mr. Hartman, *"The changing aperture shapes did give rise to artifacts under certain picture-taking conditions. We conducted a detailed laboratory study (B&H Project Report "Effects of irregular camera lens aperture on images, 15 May, 1963) and found no differences between in-focus images with circular and irregular apertures. However, out-of-focus images of objects through irregular apertures took on density distributions analogous to the iris shapes, in some cases producing even multiple images. (Later iris designs alleviated this)."*

The question presents itself - are Mr. Zapruder's images in focus? By examination they appear to be. Did an unusual iris pattern contribute to any of the artifacts seen? In my opinion I doubt it, as other camera characteristics are more probable contributors to the anomalies seen.

Part 3

Recognized Image Anomalies in the Zapruder Original Film

In the introduction to this report, we identified several image anomalies recognized by many but unexplained. I intentionally preceded a review of the anomalies with a description of pertinent camera design features that bear on the perceived problems with the images, predominately in-between the perforations.

My analysis of the image anomalies is based on the camera's image taking characteristics described in Parts 1 and 2, and from practical picture camera tests obtained with my acquired B&H 414 PD cameras. My goal here is to combine these sources so that the reader, at the conclusion of this report, can accept my analysis or has a sufficient foundation of picture data and factual camera features to develop his/her own conclusions.

Image Penetration Between the Perforations:

For us to be concerned about the quality of images between the perforation, the camera must have the capability of placing images there.

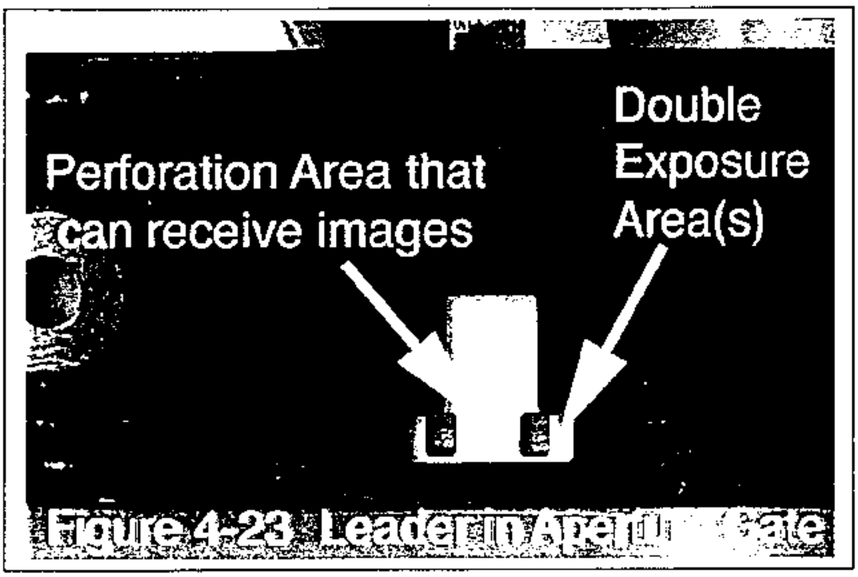


Figure 4-23 Leader in Aperture Gate

In Part I, Figure 4-9, we provided a drawing of the dimensions of the aperture cutout area. To visualize the significance of the dimensions provided, Figure 4-23 shows a section of white 8mm leader threaded in a gate. The results are seen in the accompanying photos taken with B&H 414 cameras. To reiterate, if the *exit window* of the lens is in excess of the minimum picture image diagonal, recordable scene content will be placed between the perforations.

The characteristics and depth of the image penetration are not always seen the same but do follow a consistent and repeatable pattern. The pattern is directly related to the effective image area from the *exit window* of the Varamat lens, the focal length of lens and in some cases, the aperture setting. We can show and conclude that:

- The telephoto lens setting consistently produces the maximum image penetration into the perforation area.
- Normal lens focal length produces some but not full penetration into the perforation area.
- Wide-angle lens focal length produces the least penetration into the perforation area.

By practical camera tests similar results were achieved with the Wollensak Model 53 camera with fixed focal length lenses in a turret.

Before providing justification with my camera tests, let us first examine the Zapruder film for confirmation of our hypothesis. Mr. Zapruder testified that his camera was set to "telephoto" (27mm) and we believe that the aperture was "Auto" ASA 25 with the haze filter defaulted "in".

In the Zapruder original film scenes Figure 4-1 and 4-2, we can see full image penetration into the perforation area for the approaching motorcade and the limousine scene. Zapruder's pre-motorcade test scene has less penetration and indicates a setting less than telephoto. However, Zapruder's family picture scenes (recorded in the Secret Service copies) shown with the septum line evaluation of Study 3, Figure 3-1, with a small clip repeated here as Figure 4-23 and 4-24 show the close-up baby picture with a minimum penetration and the "patio" scene with the tree with only slightly greater - but not full-penetration into the perforation area. Our analysis of these two scenes is that the focal length setting was probably Normal (13mm).

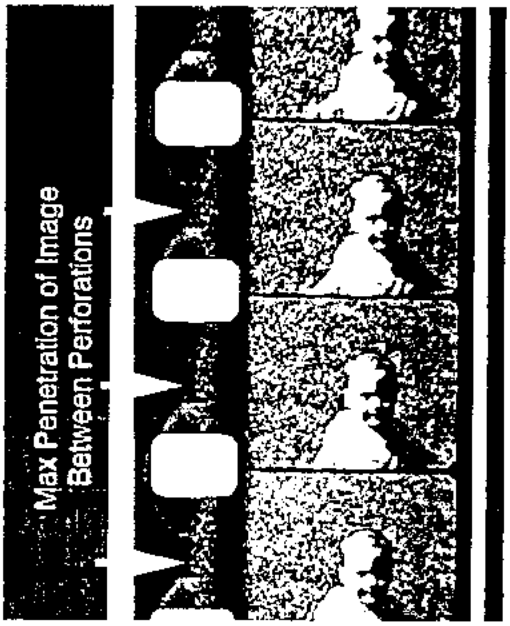


Figure 4-24 Zapruder Family Pictures Taken from Secret Service Copy

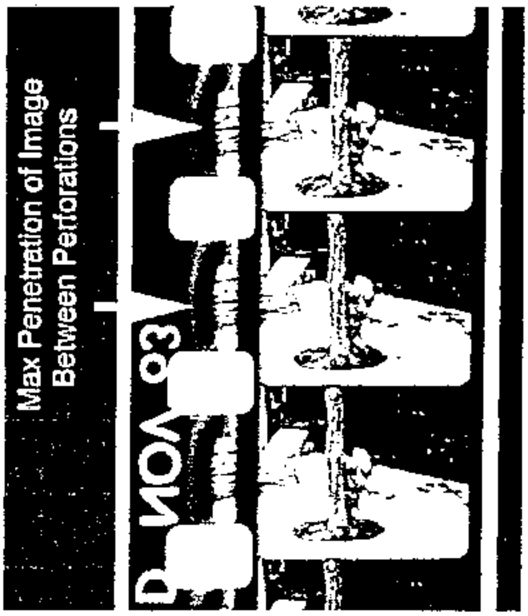


Figure 4-25 Zapruder Family Pictures Taken from Secret Service Copy

One of the most dramatic illustrations of the practical affect of the change in lens *exit window* efficiency was from my camera test in our driveway in which I transitioned from Telephoto (27mm) to Wide Angle (9mm) by straight cut (no zoom). This is shown in Figure 4-26. The same effect was observed with the Wollensak Model 53 camera.

Figure 4-26 Telephoto Lens Top Wide Angle Lens Bottom.

If one is contemplating repeating any practical tests, it is necessary to be very careful in the selection of subject matter (scene uniformity and illumination) and exposure level. (Note: Over exposure will show an increase in image penetration and extreme overexposure can produce full penetration is possible.) There is greater difficulty in repeating these conditions at low light levels. However, our goal was to replicate the Zapruder scene conditions. For example, my exposures to a neutral gray wall make the lens characteristic a little more difficult to interpret – but without question to the same conclusion. See Figures 4-27 to 4-29 that follow.

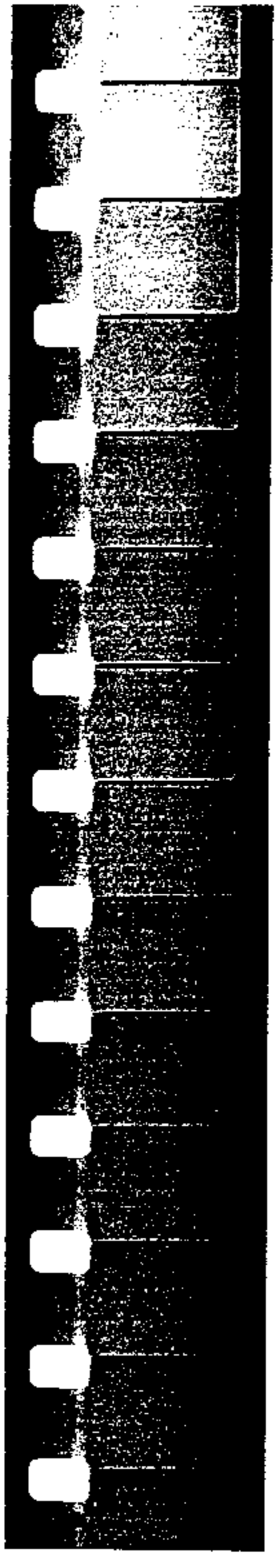


Figure 4-27 Gray Wall Exposure Series

Claw Shadow:

One of the image anomalies seen is a darker (higher density) band or wide bar in the image area between the perforations. This anomaly can be noted in the Zapruder frames Figure 4-1 and 4-2, as well as in Figure 4-27, left and in my practical test, photos throughout this report.

This higher density (band or streak) can be explained as being caused by the shadow of the intermittent claw (and its supporting arm) as it moves upward over the film to engage the following perforation and pull down the next frame. The pull-down is with the shutter closed, but the upward movement of the claw out of the perforation, over the area between the perforations, into the next perforation hole is done while the shutter is open and the film is being exposed. The claw movement over the area between the perforations reduces the amount of light reaching the film causing more density. (Less light is more density on a reversal film.) Note in Figure 4-3, the claw is centered in the perforation and does not occupy the full width of the perforation (0.072 inch).

The arm of the claw is about 0.060 inch thick and the distance traversed between perforation is 0.100 inch, but the claw moves slightly more than the film pitch length of 0.150 inch in the equivalent of the exposure time of 0.025 second. The reduction in exposure to the area behind the claw is not linear. The claw functions with a shutter crank pin engaging the claw slot giving a sinusoidal time relationship to the pulldown ratchet reentry action. The claw shadow is easily seen, but understandably its detection is scene dependent. Measurements were made of the density differences as part of microdensitometry measurements that follow.

Claw or Aperture Flare

Claw flare appears to be a very real image anomaly often, but not always, seen adjacent to the dark bar caused by the claw shadow and the normal image area. In addition, when the 8mm image is viewed normal, the bottom of the upper perforation may show some flare-like density difference. It is this perforation that "sees" the bottom of the claw arm as it enters the perforation hole and pauses before beginning its rapid positioning stroke. As mentioned above, because of the sine wave time relationship of the claw slot, shutter crank pin, there is a pause or slower motion before claw ratchet-up and after engagement of the next perforation - just before pull down. These time/rate differences may provide the opportunity for flare. The pawl is painted black, but visual examination does show it possible to reflect light because of the surface characteristics.

Notwithstanding our hypothesis, it is evident that the resulting film-image effect is device related.

Multiple Exposure Areas - Perforation-Like Images

Within the perforation area, adjacent to a perforation above or below or both, an image occurs that resembles a perforation. Those familiar with roll-film loading motion picture cameras might at first interpret the images to be associated with spool loading fog. However, they are not, the color is wrong and the positioning is consistent. Rather, the images simply represent multiple, i.e. double exposure of the area of the "excess" aperture cutout for the intermittent claw action.

In Figure 4-9 of Part 1, the camera light-limiting aperture is shown. Above the upper and below the lower perforation hole, the excess aperture cutout allows an image to be formed concurrent with the primary image. If ideally centered, it is more than half a perforation height above and below the two perforations of a primary image. This area can be seen in the photo of the aperture with leader threaded, Figure 4-23. When the succeeding image is formed it adds light to that previously formed and the preceding scene introduces light before the primary exposure causing multiple or double exposure.

The shape that this image area takes, and importantly whether it exists at all, is directly dependent on the size of the *exit window* of the lens based on the chosen focal length together with the influence of scene content.

Close examination of the gray wall scene, Figure 4-27, having less than full penetration of the image into perforation area will confirm the premise, because it is easy to visualize a less than maximum *exit window* as a series of overlapping circles with their centers at the center of each frame. Because motion picture images are successive, this causes "double" exposure of scene information, lighter density because of more light to a reversal film. The lighter density at the perforation corners may appear as, and are thus interpreted by some, as flare.

It should be noted that the semicircular pattern might not be perfectly symmetrical. This may well be do to small variations in setup of the aperture, lens centering or light uniformity distribution. Not all exposure conditions produce the phenomena, however telephoto in bright lighting conditions does. With blank frames between some test target exposures, the phenomena is visible.

Ghost Images:

In Figure 4-1of Part 1, below the perforation, there is a white object heading toward a bystander in the primary image. This so-called ghost image has caused a lot of speculation and questions from many that examined the Zapruder film. Now, by our understanding of the multiple exposure around the perforations explained above, it is reasonable to conclude the cause as simple double exposure of a primary image super imposed on the excess image of the preceding frame.

I have repeated the cause and effect in one of my camera tests of a resolution chart. Exposure was made to a "wall of resolution charts, Figures 4-28 and 4-29. Because of the light level, no flare-like effect is noted, but the multiple exposure is evident and conclusive.

Examples of Multi-exposure or "Ghost" Images:

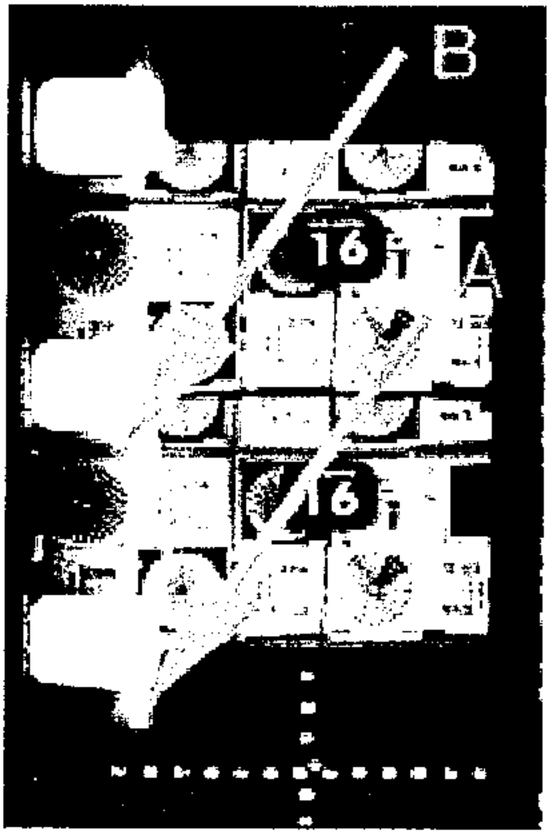


Figure 4-28 Arrow "A" shows image protrusion formed during the preceding exposure. Arrow "B" shows the multi-image.

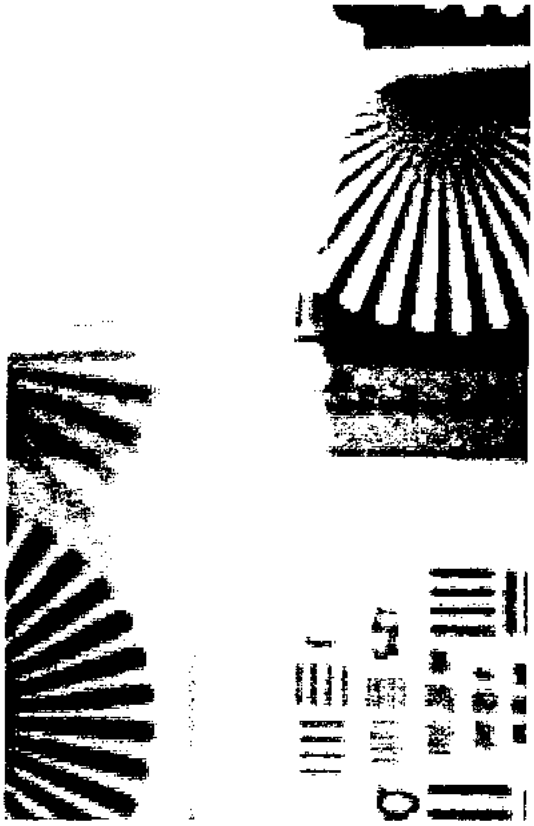


Figure 4-29 The multiple exposure shown below the perforation at the tip of the arrow "B" can be seen in this enlarged section.

First Frame Over-Exposure:

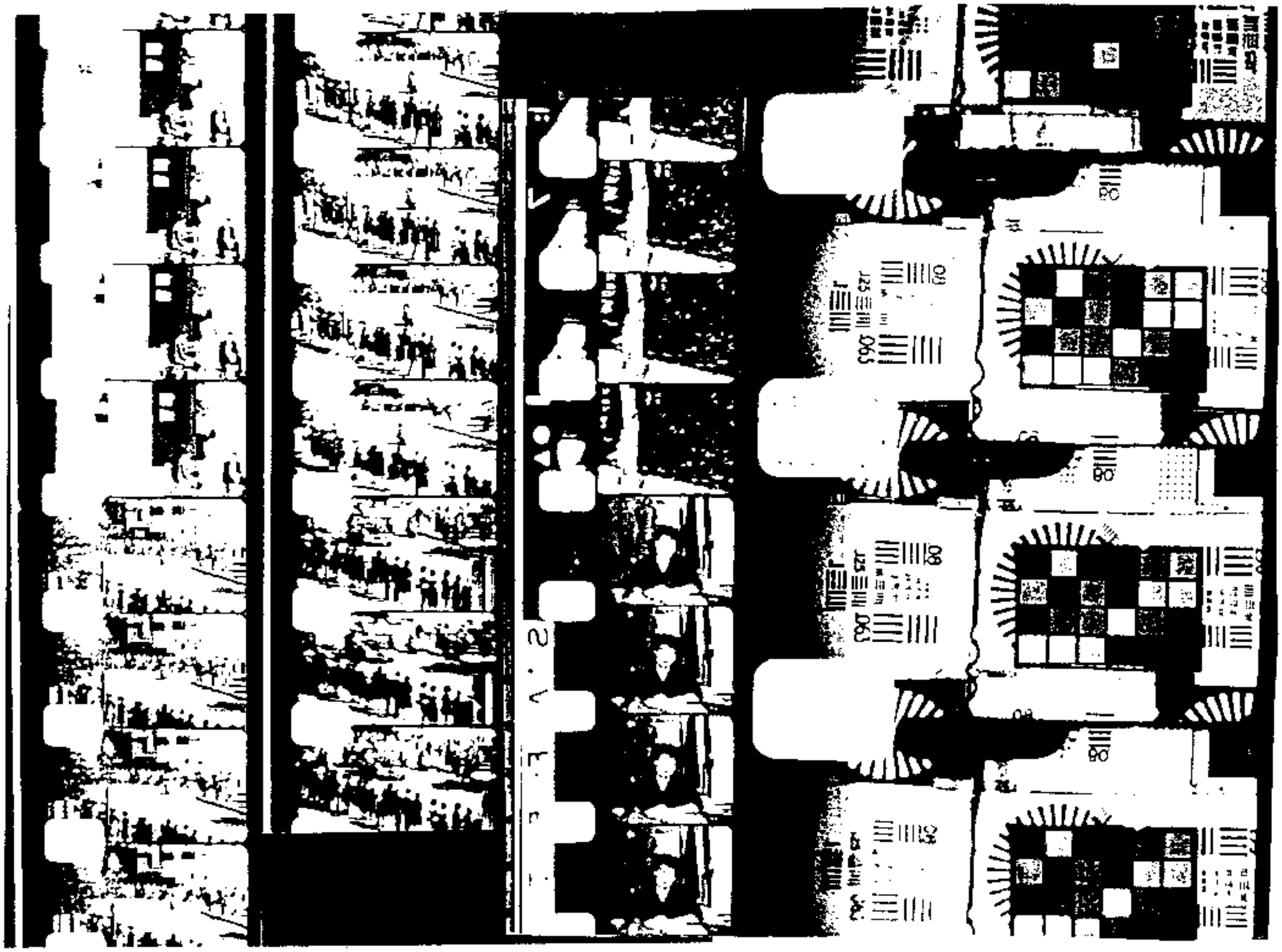
The first frame of the advance motorcade scene shows an over exposure condition, known within the motion picture engineering community as "first-frame-overexposure". In my discussions with M.E. Brown, former Manager of the 16mm and 8mm Department at Eastman Kodak, the condition was undesirable and a development/design problem to be avoided, but a not uncommon occurrence.

Mr. Zapruder's camera appears to have been prone to the problem. The Secret Service copies of his family pictures show two other occurrences of first frame over exposure shown as Figure 4 -. With my test cameras, I had one, #3, that consistently had a noticeable first frame over exposure by about one-third of a stop.

We were not given the opportunity to run a practical test with Zapruder's camera (now on display at the Sixth Floor Museum, Dallas) to determine if the first frame artifact was a consistent problem or unique to the assassination film roll. When we examined our camera for lens *exit window* size we did notice that it was possible to transmit a small amount of light with the shutter closed.

Pointing two of my loaded cameras toward the sun for two minutes did not induce the problem. The artifact is known, the exact cause could not be determined.

Examples of First Frame Overexposure



In the roll of film taken by A. Zapruder of the JFK motorcade, a fogged, first frame was noted and two scenes in the Zapruder family portion of the film, the first frame is significantly overexposed - almost as if it had been partially fogged. The hue is blue; therefore the light is reaching the film from the emulsion side.

One of my five cameras does repeatedly produce first frame over exposure, but it appears to be as a result of insufficient inertia, providing a longer shutter opening and increasing the exposure by about a third of a stop.

Above are photographs showing the first frame over exposure – left to right:

- From the A. Zapruder original - between his short burst test shot and the beginning of the motorcade. (Neg. 78069, frame 2)
- The restart of Zapruder's shooting when he paused after realizing he was filming preliminary lead motorcycles and cars. (Note: I did not detect any significant exposure level change at this transition.) (Neg. 78069, frame 6)
- An example of one of the two first frame over exposures noted in the Secret Service copy of the family portion of the roll (the first half). (Neg. 4526, frame 14)
- An example of slightly over exposed first frame from my test camera #3.

Figure 4- 30

Normal Speed vs. Slow Motion:

As mentioned in Part I, the FBI believed the timing of the shooting was critical to their analysis. One of the features of the 414PD camera was that to change from normal to slow motion velocity only required additional downward pressure on the three-way slide starting button (see page 7 of the manual), the velocity would increase to 48 fps and exposure would be automatically adjusted.

A question raised during discussions was, when the shots were fired could Zapruder have unintentionally pressed down harder and momentarily increased the velocity of the film for a fraction of a second. Would the camera mechanism allow a gradual or partial increase in velocity -- or -- would the change from normal velocity to slow motion be "positive"?

I discussed the question with David MacMillin and in his letter of 29 April 1998 he responded, *"There is no gear change to affect the change to slow motion, the member shown in photo K marked "slow motion" slides to the left and allows the governor to reach a second position that controls the camera at the slow motion speed. The centrifugal weights in the governor were 4 ball bearings approximately 3/16" diameter. A separate device not shown in these pictures included a magnet and armature, generated an electric current that increased with the camera speed (the rotating balls interrupted the magnetic field). This change in electric current was used to compensate the exposure. This was all part of a patent application of mine.*

If Zapruder had inadvertently gone into slow motion, then eased up to go into normal speed, it could be accompanied with over and under exposure frames at each speed change if his camera did not get to speed instantly upon starting or slowing down from slow motion to normal." David's patent is referenced in Part 1 of this report. Our camera test of shifting between normal and slow motion indicated it was highly unlikely that Zapruder inadvertently shifted to slow motion.

Micro Densitometry:

The micro-densitometry test objective was multifunctional. A requisite test objective was to expose to a carefully illuminated gray wall and to obtain a means of measurement of density differences in the exposed area between the perforations to compare to a central uniform scene area. As mentioned previously, studio conditions, because of limited light levels, do not produce as deep penetration in between the perforations of scenes with higher illumination.

In doing so we could:
(Results are shown in *Italics.*)

- Compare two cameras to see if the "in between perforation" artifacts were comparable. (*Cameras 1 and 3 were exactly alike and produced the same density differences.*)

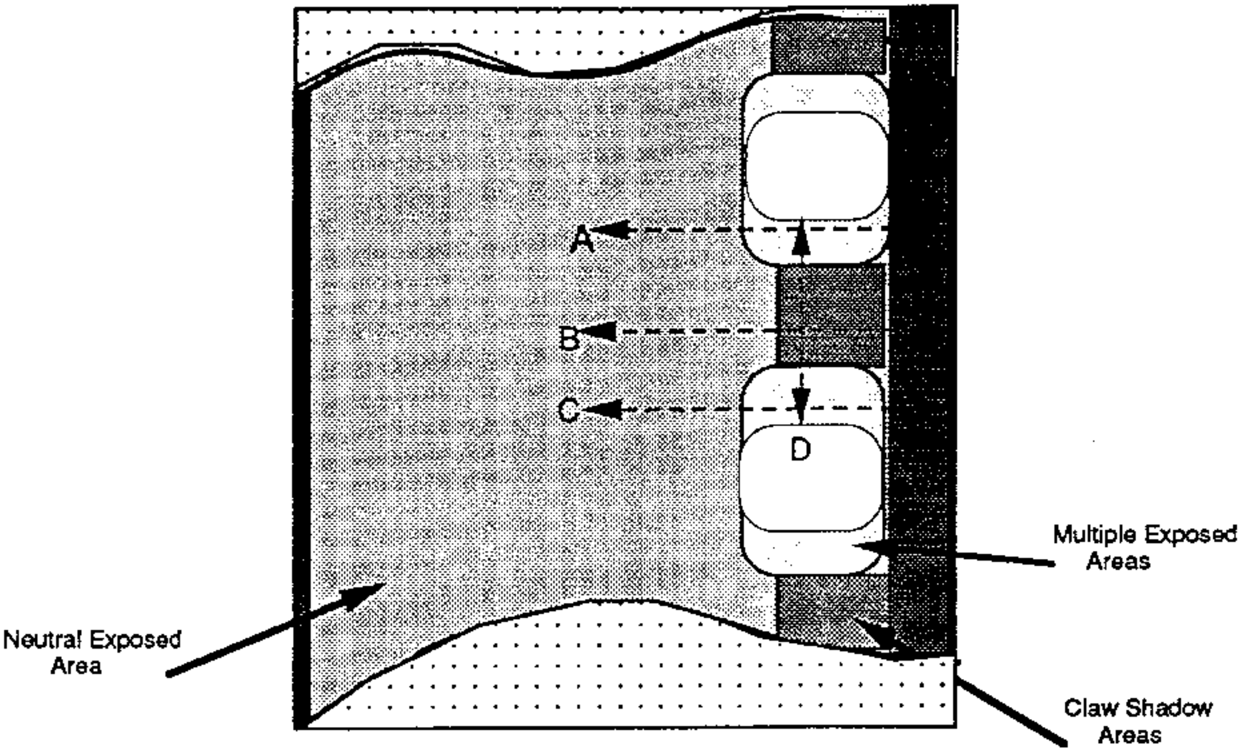
- Using one camera, shoot to the same resulting film value using neutral density filters. The studio lighting was limited, however we exposed at f2.8 and f5.6 to matched film density using ND filters. (*With the larger aperture we found less effect than with the smaller aperture - however one test may not be significant.)*

- Using one camera, obtain a several stop difference in exposure and evaluate the magnitude of density difference on "in-between" images. *(The higher densities showed a more significant effect by about one-third. A change of 0.02 density units less for low densities (0.6±) to 0.3 density units less for higher densities (1.35±.).*

- For academic understanding, measure the changes in density perf-to-perf, per "D" on a selected sample. Transverse through the multi exposure area adjacent to the claw shadow. *(This test showed the reduction of density was greater at the edge of the perforation by about the same amount as shown in transverse reading 0.03 density units. The area affected (distance from each perforation) was also the same.)*

Frame of 8mm Film Showing Multiple Exposure Areas and Claw shadow

Map of Microdensitometer TransverseTrace Areas Identified



Objective of Evaluation:

To measure the variation in density - from the perforated edge of the film strip - through selected areas of multiple exposure and claw shadow. A representative frame is selected from sample frames of exposures to a neutral density wall from two cameras, B&H #1 & #3 at three exposure levels. - f4, f5.6 and f8.

A. Close to the perforation (upper edge)
B. Between the perforations - centered as closely as possible by visual judgment.
C. Close to perforation (lower edge)
D. A representative longitudinal reading of one or two samples.

Figure 4 -31

R. J. Zavada - STUDY - 4 Sept. 1998

The test procedure constituted 27 sets of readings on seven samples from a two-camera test. Figure 4-31 shows how the readings were made.

One set of actual micro-densitometry readings of a camera test follows the end of this report as a direct appendix (for procedure reference). Some knowledge of photographic science is required for its interpretation.

For interpretation - a scale of equivalencies -

For the X-axis, PDS code values can be translated to optical density units by dividing by 800.

For the Y-axis, we can anticipate that the edge of the film is at the right edge of the chart (pixel number 2500). The outside edge of the perforation is at about 2050 pixel number and the inside edge of the perforation is about 1170 pixel number.