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DISSECTING THE ZAPRUDER BELL & HOWELL 8mm MOVIE CAMERA

Outline of a Presentation to the Movie Machine Society
Toronto Conference, 10/24/98
by Roland J. Zavada

ARRB Background Information
Brief Biography of Mr. Zavada
What Cameras did Zavada test?

Comments will be forwarded. Email: Clint Bradford

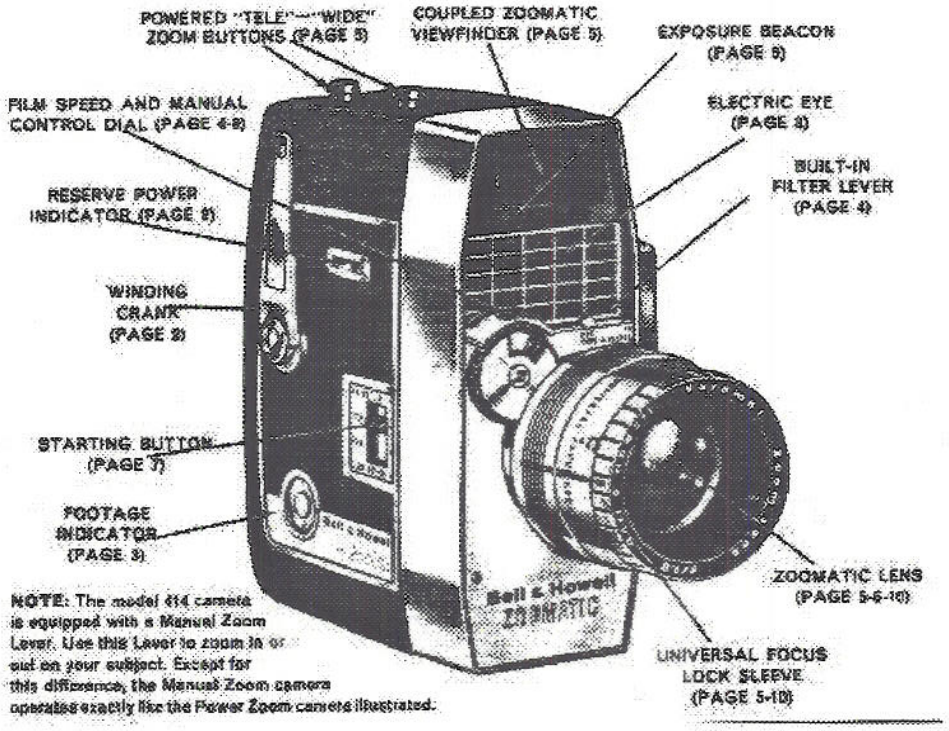
This presentation is based on a report prepared for Kodak and submitted to the Assassinations Records Review Board. The Kodak report is now in the possession of the National Archives who are responsible for its control and distribution. Permission was granted for me to make this technical presentation on the image capture characteristics of the Bell & Howell Model 414PD 8mm roll film camera to the MMS. The Model 414PD camera was used by Abraham Zapruder to film the assassination of President John F. Kennedy. It is the intention of the National Archives to make the full report public in the near future - possibly including distribution on the World Wide Web. This handout therefore provides only a brief synopsis and outline. -*Roland J. Zavada, 10/24/98*

Objective: This study resulted from a request of the Assassinations Records Review Board to Kodak, to conduct film tests using a Model 414 PD Bell & Howell Zoomatic Director Series camera to determine whether the recognized anomalies in the Zapruder film held by the National Archives are borne out by actual tests.

Introduction

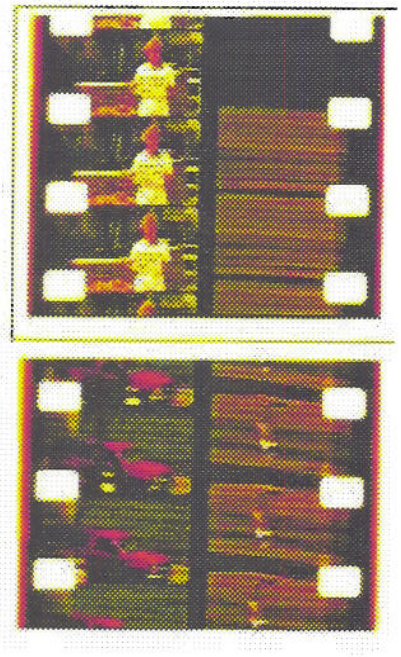
Just after noon on November 22, 1963, Mr. Abraham Zapruder, a woman's clothing manufacturer, climbed onto a small concrete pedestal in Dealey Plaza with his 8mm movie camera. After President Kennedy's motorcade came into view and passed, Mr. Zapruder's 26 second film record of the assassination became the most significant amateur recording of a news event in history.

The Bell & Howell 414PD 8mm camera was, in 1963, a top of the line, high quality 8mm amateur movie camera. The optics were outstanding, the drive mechanism provided consistent long-run exposure time/per wind, the automatic exposure mechanism was of award winning design that yielded excellent results and the camera had a power zoom lens. The "P" in the model reference stood for "Power Zoom" and the "D" for "Dual Electric-Eye." The image formed within the standardized projectable area had no flaws or faults. Why then have we made an extensive study of the camera's image capture characteristics?



The camera used is not untypical of several models that position the film with its claw moving in an aperture cutout area adjacent to the image forming picture area. Consequently, scene information falls into this unmasked area due to the excess (circular) imaging area produced by the lens. For normal home movie projection this additional recorded scene information would be of no consequence as the projector aperture would hold back or mask-out this area.

We have the typical camera aperture area (i.e. the images that would be viewed by standard projection), and an additional area where the image extends into the area between the perforations and adds to the total scene content. To some students of the assassination, the Zapruder original film contains several image anomalies - almost all being related to the scene information recorded or imaged into the area between the perforations. (See sample frames below shot in Dealey Plaza.)



There is great significance attached to this area by various researchers who speculate that the anomalies may represent not the peculiar optics of Zapruder's Bell & Howell camera but rather, evidence of film alteration. It is important, therefore, to understand how the camera optics record images in this area and why certain anomalies are present - which is part of the objective of this study.

Overview of Image Anomalies:

The image characteristics that have been identified as "those of concern" are inconsistencies; i.e. they are not the same density, color and quality as those contained in the primary image area. The cause of those inconsistencies thus provides a focus for our review of camera characteristics. A look at a few frames from the Zapruder "in camera" original, provide a "picture" of the image characteristic that will be the bases of detailed discussions. (See Photo from the Warren Commission Exhibit.)

Image anomalies or characteristics that were addressed are:

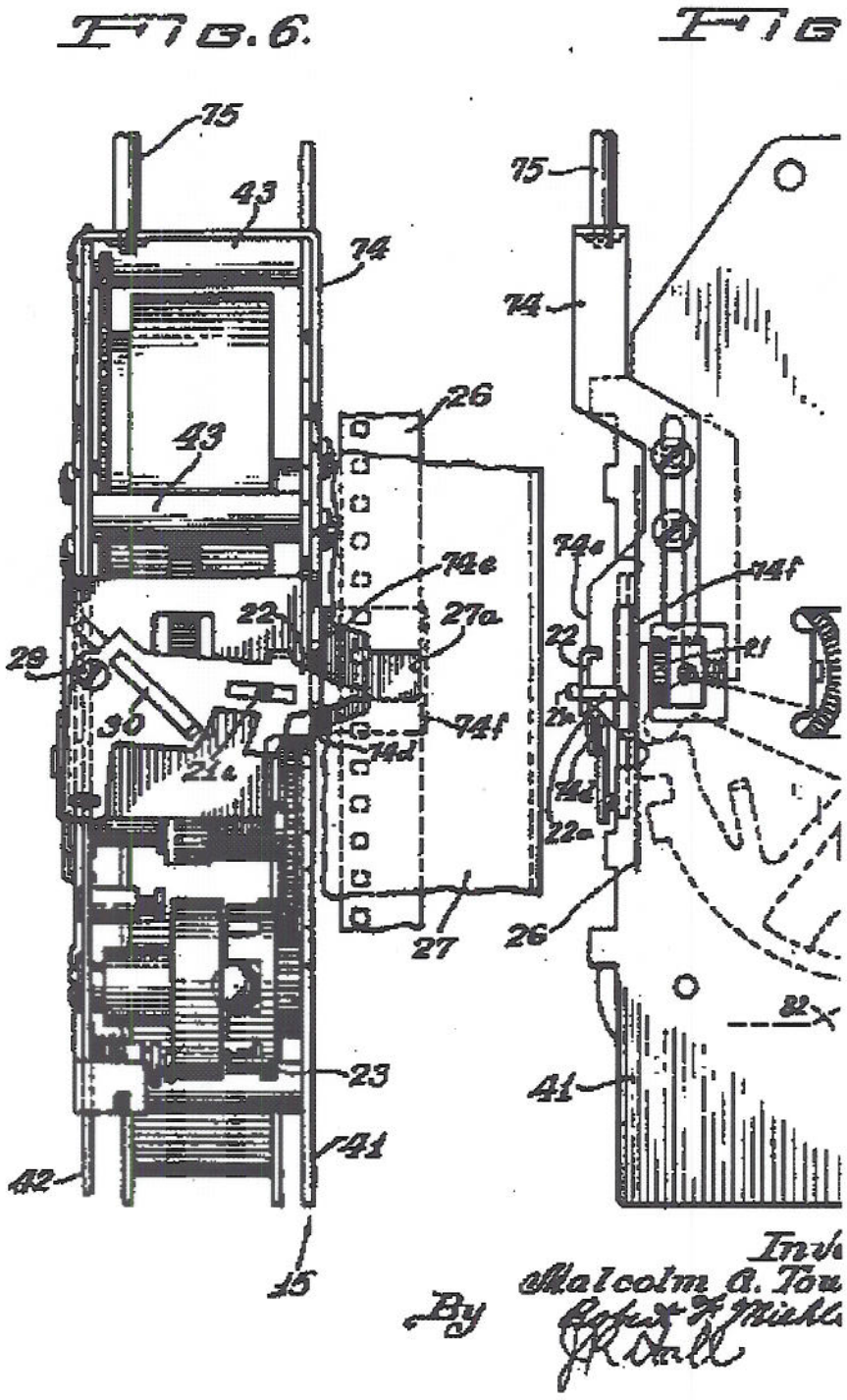
Claw Shadow -Between the perforations there is a broad bar where the image has more density (darker) than the primary image area.

Claw or aperture Flare - Sometimes adjacent to the dark (claw shadow) bar and between it and the primary image is a "streak" lighter than the dark bar and the adjacent image.

Multiple Exposure Areas Adjacent to Perforation - Sometimes there appears a lighter image area resembling images of perforation holes.

Ghost Images - Sometimes there appears to be *"ghost"* images such as a motorcycle fender. These are real images, which because of the design of the claw cutout area occur simultaneously above and below the perforation holes of the primary image being formed.

First Frame Overexposure - Occurs in the Zapruder original with his first exposure of the motorcade and at least twice in his filming of the first half of the roll. The possible causes of the fogged or lesser density first frame are reviewed, to the best extent possible - recognizing the limitation that we could not conduct a practical test with the Zapruder B&H 414 PD camera.



The camera mechanism includes a negator spring motor drive which, when released by a pivotal movement of a control arm from its position (by pushing down on the start button), serves to rotate a scroll gear to drive a worm (gear). This worm serves to rotate a film footage indicator dial, and to rotate a gear carrying a crank pin to oscillate a shuttle or film pulldown claw and rotate a shutter, as well as drive a governor, and to rotate gears. The shuttle is urged by spring (pressed against the film) toward feeding engagement with the film (i.e., to engage the perforation holes) in a position between an aperture plate incorporating an exposure aperture (area) and a pressure plate (to hold

the film flat and motionless during exposure). The shuttle is pivoted on a pin. The gear also carries a known disc segment type of shutter which covers the aperture during frame-by-frame feed of the film and when the camera is stopped.

Film Intermittent:

In the ratchet type, the claw is normally brought into contact with the film by the action of a light spring. The claw can reciprocate (out of one perforation into the next) in a single plane because its upper edge is tapered so that it will ratchet or cam out of engagement with a perforation at the beginning of the upward movement. The claw will ride along the surface of the film through its entire upward or return stroke until it drops into the succeeding perforation hole. This type of mechanism is the simplest form of the two mentioned, and is the type employed in the Bell & Howell 414PD Camera. (See Drawing)

Camera Aperture:

The drawing shown provides the representative dimensions of the aperture, which limits image height, inside edge and shows the cutout for the intermittent claw. The characteristics of the aperture cutout are directly related to our study of image anomalies, note the size and location of the cutout for the pulldown claw adjacent to the Standardized (0. 192 in. nom. width) image area. Note that the height of the opening for the claw movement is necessarily greater (0.263 in.) than the perforation pitch (0. 150 inch) plus one perforation height (0.050 inch). The significance of the size of this opening will be emphasized when we discuss *Multiple Exposure Areas.*

Shutter/Exposure Time:

The shutter, for the great majority of motion picture cameras, employs a rotating disc with an open sector to allow light from the lens to reach the film during its stationary exposure period. During the period when the opaque sector of the shutter obscures the light from the lens, the next frame of the film is moved and relocated by the intermittent. The Bell & Howell 414PD camera uses a shutter having an open sector the equivalent of about 165' to 170' resulting in an exposure time of 0.025 second (or 1/40th of a second) per frame.

Motor/Governor:

Early spring wound movie cameras were limited by their clock-spring wind-up motors which were a challenge to designers to maintain constant torque to transport the film at a uniform velocity because of inertial (acceleration) effects from the start of the clutched spring motor. Their run time was relatively short. In the late 50's and early 60's a major change occurred for the high-end cameras with the introduction of the negator spring. The B&H 414 Camera series was the first of the Bell & Howell line to incorporate the negator spring. The negator spring motor provided an almost constant torque throughout its effective run time and essentially "negated" transport speed effects. Further, the run time was extended significantly. The differences in run time were in the order of double, from 25 - 30 seconds to more than a minute (15 feet of film).

Film Velocity/Frame Rate:

The question of frame rate of the Zapruder camera was an important technical consideration of the FBI in their investigation of the timing of the three shots. The FBI reported that their studies showed the camera to be operating at 18.3 fps, or 2.3 fps fast according to the (then) published standard and the reference in the owner's manual.

Evolution of Standards to Higher Frame Rates: It has been acknowledged that Bell & Howell's and Eastman Kodak's engineering practice for cameras moved toward 18 fps in the late 50s, and that this velocity was not uncommon in USA practice. The committee action to change standards takes time. The published standard for camera velocity in use in 1963 issued in 1954. Standards reflect practice and the evolutionary change to the higher frame rate of 18 frames per second was subsequently recognized in American National Standards that issued in October of 1964 . for Camera and Projector Usage - PH22. 21 and PH22.22. Bell & Howell testing confirmed that the Zapruder camera operated at slightly faster than 18fps - meeting the requirements of the revised standard.

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. That quality position was confirmed in correspondence from the former Director of Engineering of the Optical Division, Mr. Rudolf Hartmann. He related: "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.

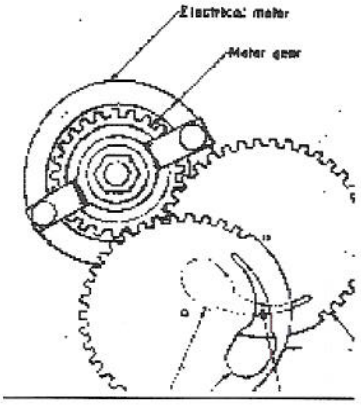
"Windows" of the Lens:

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. 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. 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. (See drawing and photos on cover page.)

Electric Eye and Iris Diaphragm:

An article, *A Direct Drive Automatic Iris Control*, by LaRue, Bagby, Bushman, Feeland and MacMillin was published in the September 1958 issue of the SMPTE Journal and gives the reader design and engineering details on the automatic exposure 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.)

The iris diaphragm in the 414 camera series uses two overlapping disks each of which has a wedge shaped angular slot. The intersection of the two slots forms the variable aperture. Gear teeth are formed on the periphery of the disks that engage a gear mounted on the meter coil. (See drawing below.)



Unusual Iris Shapes:

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. 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. If the subject is not in focus inversion, multiple images, etc. can and do occur. However, if the image is focused properly, the iris pattern makes no difference. 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.

Recognized Image Anomalies in the Zapruder Original Film

Image Penetration 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; and

Wide-angle lens focal length produces the least penetration into the perforation area.

Claw Shadow

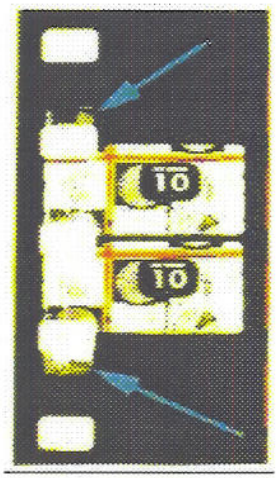
One of the image anomalies seen is a darker (higher density) band or wide bar in the image area between the perforations. This anomaly can be noted in the Zapruder frames as well as my practical test, photos. This higher density (band or streak) can be explained as being caused by the shadow of the intermittent 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.) 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.

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. (See also cover photo.)

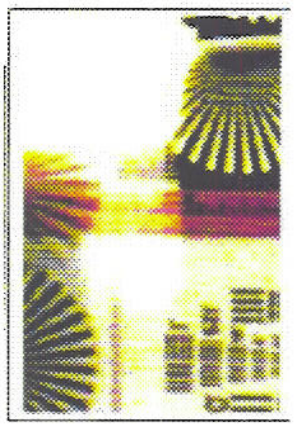
Multiple Exposure Areas - Perforation-Like Images

Within the perforation area, adjacent to a perforation above or below or both, an image occurs that resembles a perforation. The images simply represent multiple, i.e. double exposure of the area of the "excess" aperture cutout for the intermittent claw action. Above the upper and below the lower perforation hole, the excess aperture cutout allows an image to be formed concurrent with the primary image. When the succeeding image is formed it adds light to that previously formed 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. Not all exposure conditions produce the phenomena, however telephoto in bright lighting conditions does. With blank frames between some test target exposures, the phenomenon is visible and multiple exposures adjacent to the perforations are easily seen. (See photo below.)



Ghost Images:

In the Zapruder motorcade scene, below the perforation, you were shown 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. (See ghosting on test chart below.)



First Frame Over-Exposure:

The first frame of advance motorcade scene shows an over exposure condition, known 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.

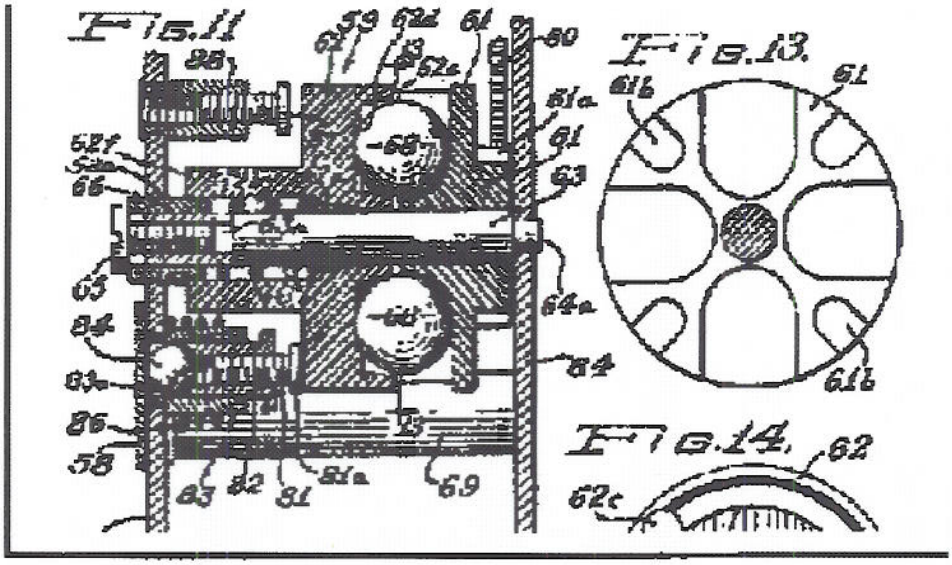
Mr. Zapruder's camera appears to have been prone to the problem. The Secret Service copies of his family pictures show two other occurrences of first frame over exposure. With my test cameras, I had one, #3, that consistently had a noticeable first frame over exposure by about one-third of a stop. We were not given the opportunity to run a practical test with Zapruder's camera to determine if the first frame artifact was a consistent problem or unique to the assassination film roll.

Conclusion

It is my conclusion that all the inter-perforation image anomalies identified can be explained by the design and image

capture characteristics of the Bell & Howell 414PD Camera.

Roland J. Zavada, 10/24/98



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